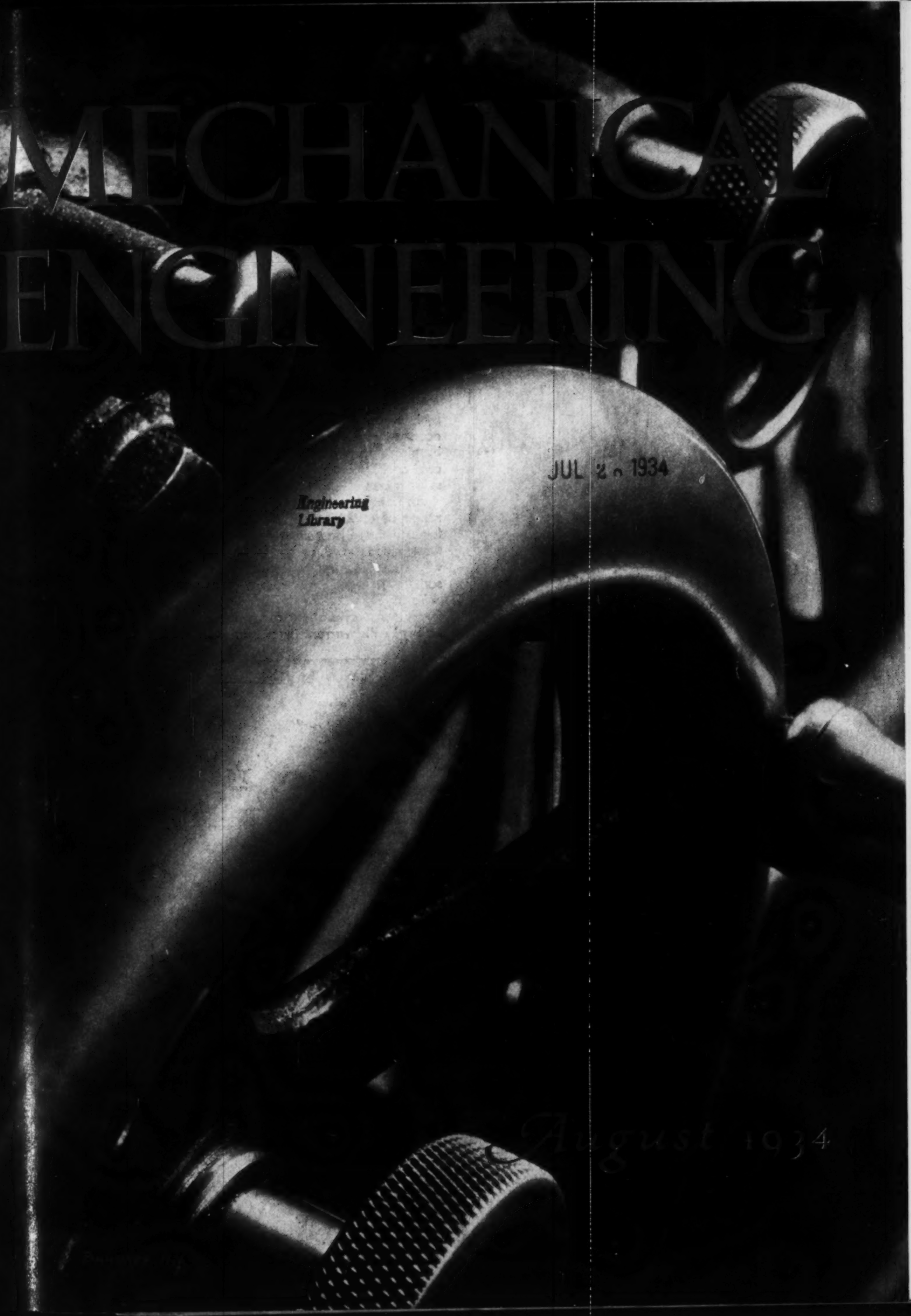
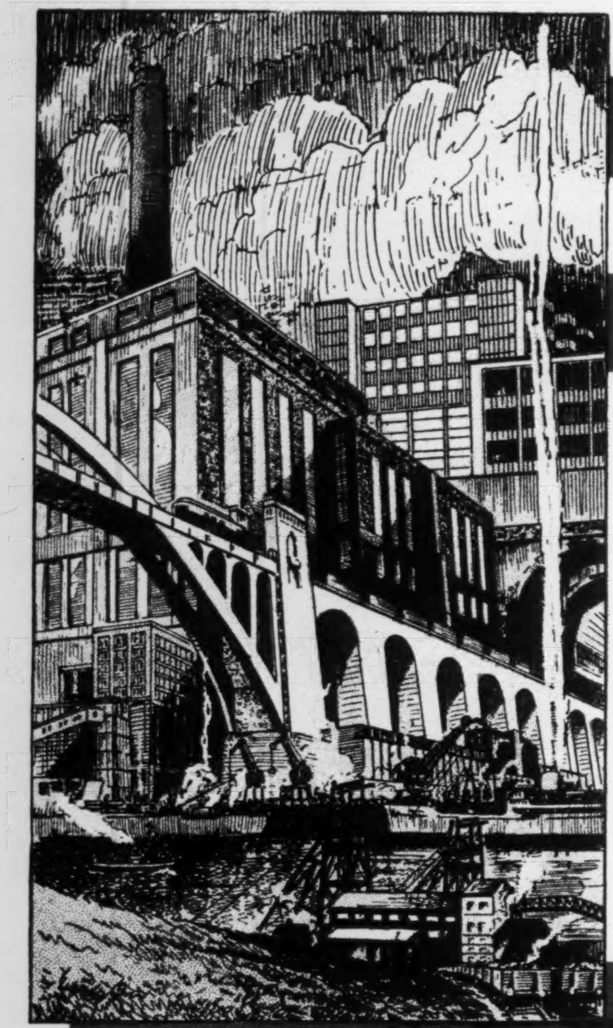


MECHANICAL ENGINEERING

August 1934

JUL 2 [illegible] 1934

Engineering
Library



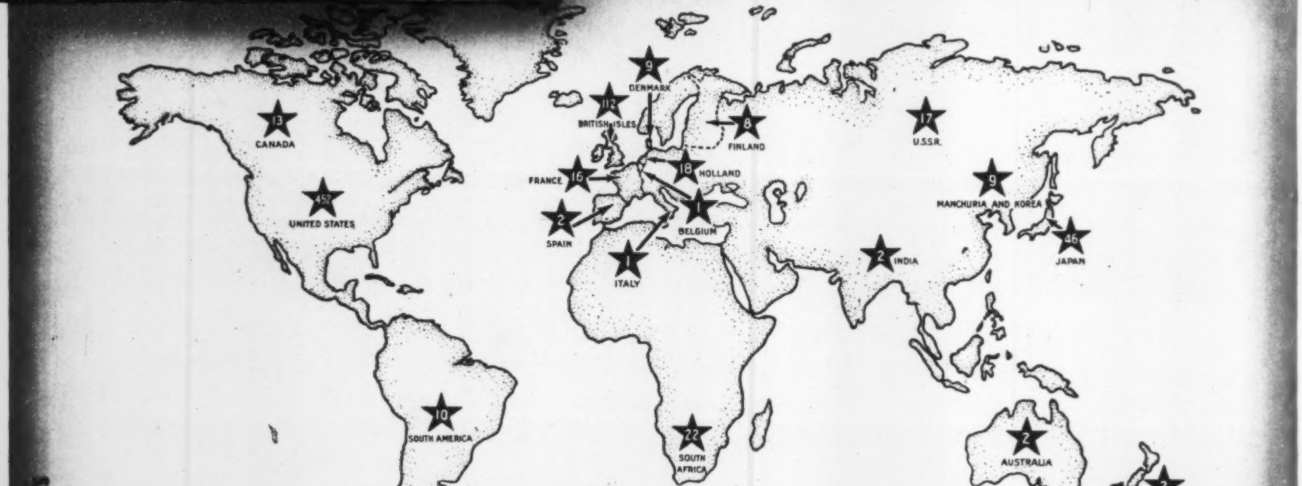
Througout the world
BAILEY WALLS
are reducing operating costs

Whether in a lignite-burning standby unit in New Zealand, an industrial plant in Russia, or a typical high-load-factor central station in the United States, the installation of a Bailey Water-Cooled Furnace will insure higher operating efficiency and attendant lower power costs.

The many advantages of this construction are not restricted by international boundaries or by conditions most adverse to economical operation; this construction is adapted to the burning of all classes of coal from anthracite to bituminous coal and lignite, covering a wide range of moisture, volatile, sulphur and ash, as well as ash-fusing temperatures.

Furthermore, the Bailey Wall alone can meet this entire range of conditions. The flexibility of construction permits a furnace shape best suited to the space and combustion conditions encountered, and will present hot surfaces in the zones which must be hot, and cold surfaces where required in the same unit.

Today's profits are dependent on savings . . . savings result from lower operating costs. The economic advantages of Bailey Walls warrant investigation.



ELECTRICAL GOODS PLANTS
PULP AND PAPER MILLS
TOBACCO FACTORIES
SUGAR REFINERIES
OIL REFINERIES
DISTILLERIES
STEEL MILLS
TEXTILE MILLS
RUBBER FACTORIES
CHEMICAL PLANTS
MACHINERY WORKS
AUTOMOTIVE PLANTS
COPPER REFINERIES
STEEL FOUNDRIES
SOAP WORKS
COLLIERIES
RAILWAYS
STEAMSHIPS
GLASS FACTORIES
CENTRAL STATIONS
FURNITURE FACTORIES
PAPER BOX FACTORIES

The number of Bailey Walls in service is shown on the map above . . . installations ranging from that on a central station boiler delivering more than 1,000,000 lb. of steam per hour to that on a Great Lakes Steamer requiring 60,000 lb. of steam per hour for all purposes.

The Babcock & Wilcox Company . . . 85 Liberty Street . . . New York . . . N.Y.

BABCOCK & WILCOX

MECHANICAL ENGINEERING

Published by The American Society of Mechanical Engineers

Volume 56 Number 8

Contents for August, 1934

PENSTOCKS FOR BOULDER DAM . . . . *C. M. Day and Peter Bier* 451
COST CONTROL . . . . *L. P. Alford* 466
MANUFACTURING TECHNIQUE OF THE UNITED STATES . . . . *R. E. W. Harrison* 468
CONTROL OF PRODUCTION IN A DYNAMIC ECONOMY . . *E. D. Smith* 470
SOARING PLANES . . . . *R. S. Barnaby* 476
STEAM AND POWER SUPPLY—A DISCUSSION 480
NOMINATIONS FOR OFFICERS OF THE A.S.M.E., 1934–1935 503
A.S.M.E. MEETS AT DENVER, COLO. 506

EDITORIAL 484
SURVEY OF ENGINEERING PROGRESS . 486
CORRESPONDENCE 498
A.S.M.E. BOILER CODE 499
BOOK REVIEWS AND LIBRARY NOTES . 501
WHAT'S GOING ON 503

DISPLAY ADVERTISEMENTS 1
WHAT'S NEW 2
PROFESSIONAL SERVICE 23
CLASSIFIED ADVERTISEMENTS . . . 24
INDEX TO ADVERTISERS 26

OFFICERS OF THE SOCIETY:

Paul Doty, *President*
Erik Oberg, *Treasurer*
Calvin W. Rice, *Secretary*

PUBLICATION STAFF:

George A. Stetson, *Editor*
Frederick Lask, *Advertising Mgr.*

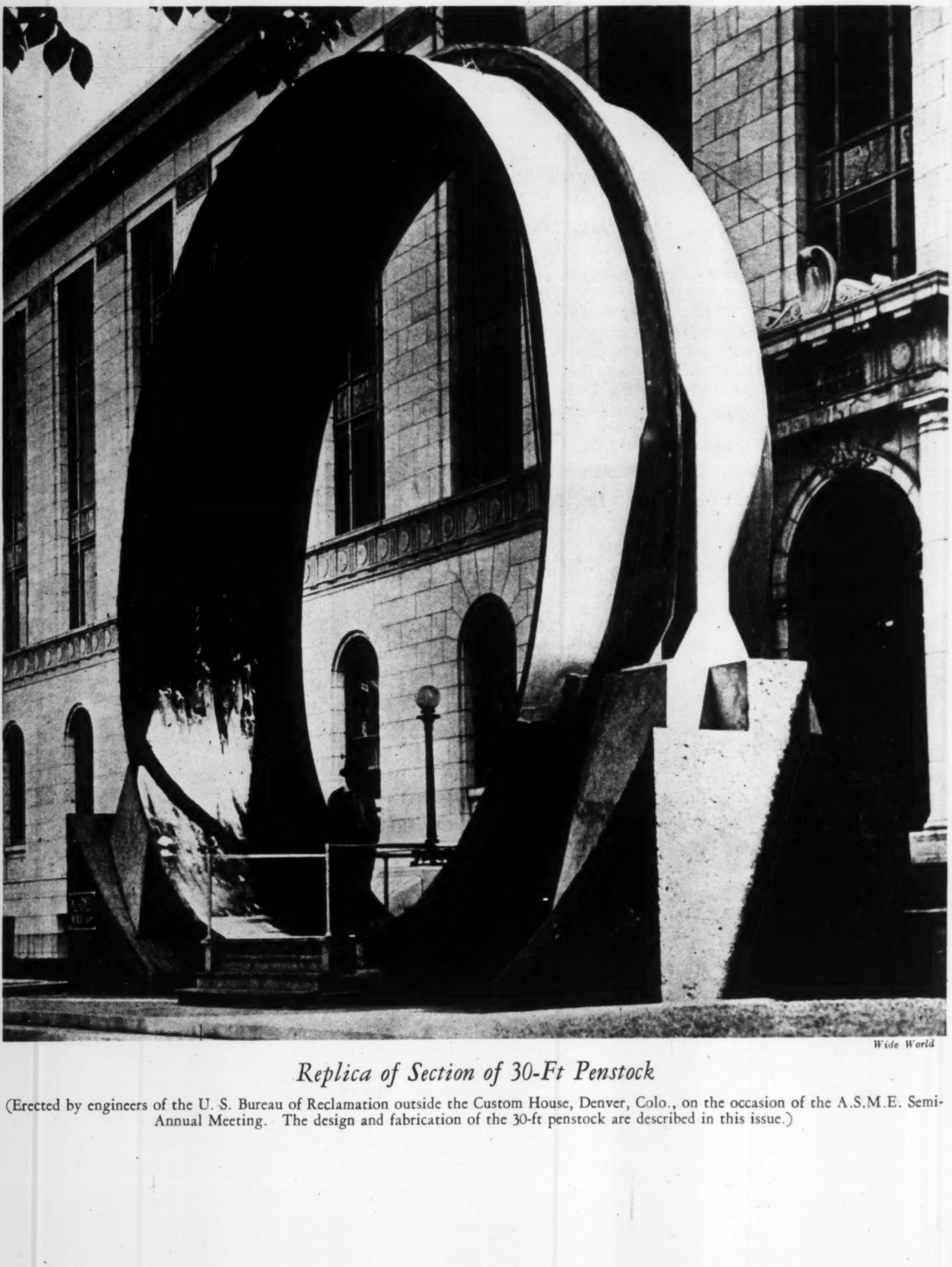
COMMITTEE ON PUBLICATIONS:

L. C. Morrow, *Chairman*
S. W. Dudley
S. F. Voorhees
W. F. Ryan
G. F. Bateman
M. H. Roberts
C. E. Davies, *Secretary to Committee on Publications*

ADVISORY MEMBERS OF THE COMMITTEE ON PUBLICATIONS:

E. L. Ohle, St. Louis, Mo.
E. B. Norris, Blacksburg, Va.
A. J. Dickie, San Francisco, Cal.
Junior Member, O. B. Schier

Published monthly by The American Society of Mechanical Engineers. Publication office at 20th and Northampton Streets Easton, Pa. Editorial and Advertising departments at the headquarters of the Society, 29 West Thirty-Ninth Street, New York, N. Y. Cable address, "Dynamic," New York. Price 60 cents a copy, $5.00 a year; to members and affiliates, 50 cents a copy, $4.00 a year. Postage to Canada, 75 cents additional, to foreign countries, $1.50 additional. Changes of address must be received at Society headquarters two weeks before they are to be effective on the mailing list. Please send old as well as new address ....By-Law: The Society shall not be responsible for statements or opinions advanced in papers or ....printed in its publications (B2, Par. 3)....Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879 ....Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921 ....Copyrighted, 1934, by The American Society of Mechanical Engineers



Wide World

Replica of Section of 30-Ft Penstock

(Erected by engineers of the U. S. Bureau of Reclamation outside the Custom House, Denver, Colo., on the occasion of the A.S.M.E. Semi-Annual Meeting. The design and fabrication of the 30-ft penstock are described in this issue.)

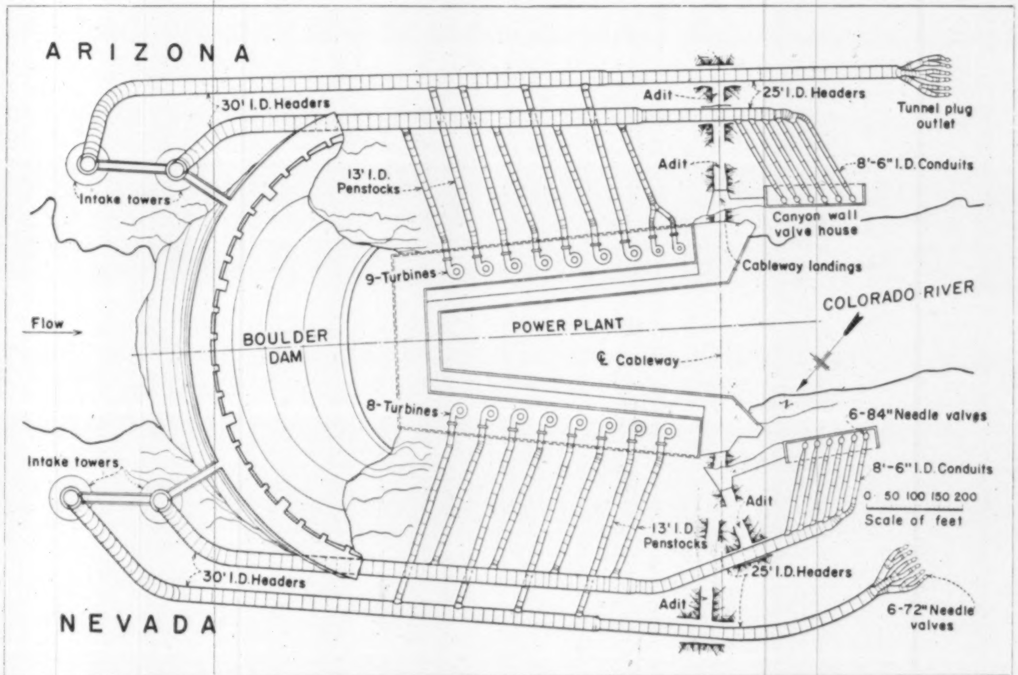

ARIZONA
30' I.D. Headers
Intake towers
13' I.D. Penstocks
Adit
25' I.D. Headers
Tunnel plug outlet
Adit
8'-6" I.D. Conduits
Canyon wall valve house
Cableway landings
9-Turbines
COLORADO RIVER
Flow
BOULDER DAM
POWER PLANT
℄ Cableway
8-Turbines
6-84" Needle valves
Intake towers
8'-6" I.D. Conduits
Adit
0 50 100 150 200
Scale of feet
13' I.D. Penstocks
25' I.D. Headers
30' I.D. Headers
Adit
6-72" Needle valves
NEVADA

FIG. 1 GENERAL PLAN OF BOULDER DAM, POWER PLANT, AND OUTLET WORKS

PENSTOCKS FOR BOULDER DAM

Design, Fabrication, and Installation of Welded Plate-Steel Pipes and Special Fittings of Unusual Magnitude

By C. M. DAY[1] and PETER BIER[2]

THE ORIGINAL plans for the construction of Boulder dam provided four concrete-lined diversion tunnels 50 ft in diameter, two of which were to be plugged and each to be used as a power penstock for serving four hydraulic turbines in the power plant on each side of the river, and two additional concrete-lined penstock tunnels 30 ft in diameter at a higher elevation, each of which would serve four hydraulic turbines on each side of the river. The penstocks between the turbines and main tunnels were to be steel pipes 11 ft in diameter embedded in concrete.

Because of the limited time allowed for the preparation of designs and specifications for Boulder dam, an investigation of the stresses and other conditions that might exist in these tunnels was not made until after the contract was awarded.

In a concrete-lined tunnel placed under high internal pressure the expansion of the bore due to the elastic yielding of the rock may result in splitting the rock and lining longitudinally with the result that water entering the cracks under pressure may cause them to be extended progressively until some point of relief is reached. This condition can be determined by stress analysis and is proved by experience.

Analysis also shows that a concrete-lined tunnel having a thin plate-steel lining with plate thickness less than would be required to resist the internal pressure if acting alone cannot be expected to have sufficient strength to bring about the required slippage between the steel and concrete when a crack forms, with the probability that the steel liner may be torn along the crack. Engineering literature reveals that this action has been observed, particularly in Norway.

Mathematical analyses for a concreted tunnel, 50 ft in diameter and lined with steel, showed that a liner 4 in. thick would carry a pressure of 250 lb per sq in. with a stress of 18,750 lb per sq in. without assistance from the rock. A steel liner 3 in. thick would carry the same pressure with a stress of 16,000 lb with assistance from the rock. In either case the cost of such a plan precluded its use.

A study of the requirements of the power plant and for release of water from the reservoir showed that four steel pipes each 30 ft in diameter, installed in the tunnels as detached conduits, would satisfy the conditions. It was also determined, after investigating flow conditions and water hammer, that by using high-strength steel plates and providing longitudinal joints so welded that a joint efficiency would give a strength equal to that in the plates, the maximum plate thickness would not exceed $2^{3}/_{4}$ in. The design of the penstocks therefore proceeded on this basis. The plan has the added advantage that the pipes are accessible for inspection and maintenance.

The many unusual and practically unexplored problems connected with conduits 30 ft in diameter made it seem wise to investigate the possibilities of alternative designs in order to keep within accustomed limits of fabrication and transportation. This was taken into consideration when, in the winter and spring of 1932, detail designs and specifications were prepared for the fabrication and installation of the steel pipes, and as a result, three distinct conduit schemes were developed, each in sufficient detail for bidding purposes. The first scheme was based on headers 30 ft in diameter, one for each of four tunnels, with four branch penstocks 13 ft in diameter leading to the turbines. The 30-ft headers were then reduced to 25 ft in diameter, from which smaller branch pipes led to the outlet valves. The second scheme provided four $17^1/_2$-ft headers in each of the four tunnels, from which 13-ft penstocks branched off to the turbines and conduits of smaller size led to the outlet valves. The third scheme consisted of seven 13-ft individual penstocks and conduits in each of the four tunnels, leading to the turbines and valve outlets below.

---

[1] Mechanical Engineer, U. S. Bureau of Reclamation, Denver, Colo.

[2] Engineer, Bureau of Reclamation, Denver. Assoc-Mem. A.S.M.E.

Presented on "Reclamation Bureau Night," at the Semi-Annual Meeting, Denver, Colo., June 25 to 28, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Published by permission of the United States Bureau of Reclamation.

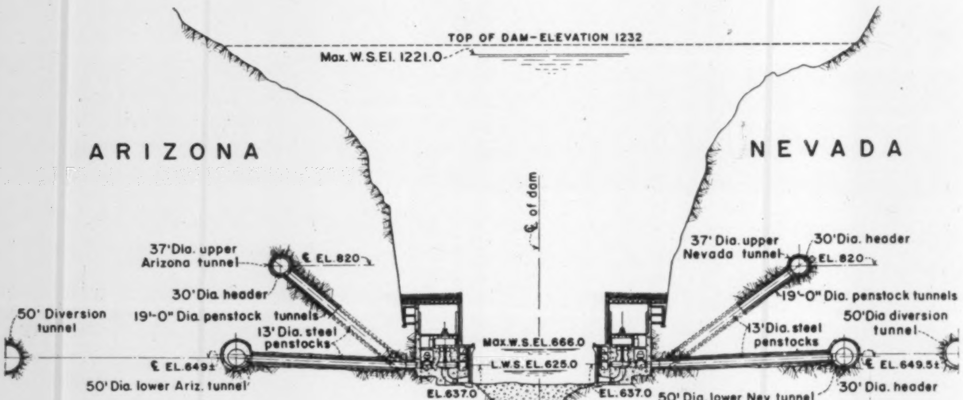

TOP OF DAM—ELEVATION 1232
Max. W.S.El. 1221.0
ARIZONA
NEVADA
℄ of dam
37' Dia. upper Arizona tunnel
℄ EL. 820
30' Dia. header
50' Diversion tunnel
19'-0" Dia. penstock tunnels
13' Dia. steel penstocks
℄ EL. 649±
50' Dia. lower Ariz. tunnel
EL. 637.0
Max.W.S.EL.666.0
L.W.S.EL.625.0
EL. 637.0
37' Dia. upper Nevada tunnel
30' Dia. header
EL. 820
19'-0" Dia. penstock tunnels
50' Dia diversion tunnel
13' Dia. steel penstocks
℄ EL. 649.5±
30' Dia. header
50' Dia. lower Nev. tunnel

FIG. 2 SECTION OF POWER PLANT, TUNNELS, AND PENSTOCKS

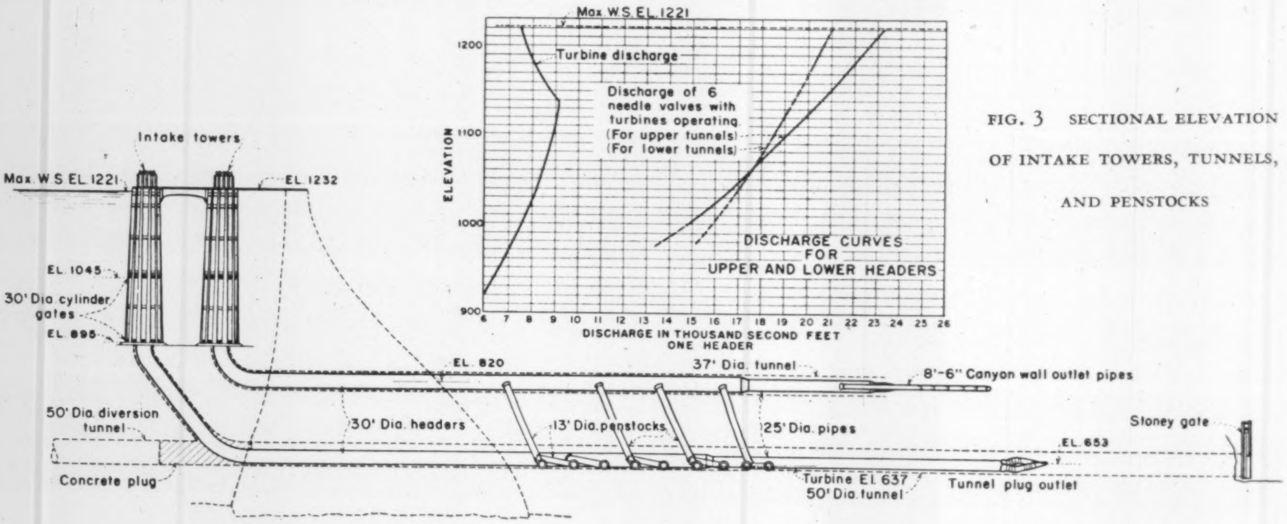

Max. W.S. EL. 1221
Turbine discharge
Discharge of 6 needle valves with turbines operating
(For upper tunnels)
(For lower tunnels)
ELEVATION
1200
1100
1000
900
DISCHARGE CURVES FOR UPPER AND LOWER HEADERS
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
DISCHARGE IN THOUSAND SECOND FEET ONE HEADER
Intake towers
Max. W.S. EL. 1221
EL. 1232
EL. 1045
30' Dia. cylinder gates
EL. 895
EL. 820
37' Dia. tunnel
8'-6" Canyon wall outlet pipes
50' Dia. diversion tunnel
30' Dia. headers
13' Dia. penstocks
25' Dia. pipes
Stoney gate
EL. 653
Concrete plug
Turbine El. 637
50' Dia. tunnel
Tunnel plug outlet

FIG. 3 SECTIONAL ELEVATION OF INTAKE TOWERS, TUNNELS, AND PENSTOCKS

The lowest bids were submitted on the 30-ft pipe system, with two companies bidding; the highest bids were received on the four-pipe (or $17^1/_2$-ft pipe) system, with three companies submitting bids.

In accordance with computations made for the three schemes, the 30-ft pipe system showed the lowest hydraulic loss, but also the highest annual maintenance cost. After capitalizing these annual cost items for each scheme and adding them to the prices bid, the 30-ft diameter pipe system was established as the most economical, and a contract was awarded to the Babcock & Wilcox Co. for the lump sum of $10,908,000. This, however, did not include the cost of the freight on the plates from the mill to the fabricating plant, nor did it include the cost of handling the completed pipe sections from the fabricating plant to the tunnel adits.

Fig. 1 shows the general plan of the dam, power plant, tunnels, and outlet works and Fig. 2 a sectional elevation. Four reinforced-concrete intake towers[3] will be constructed, each having a base diameter of 82 ft, tapering to a diameter of 64 ft at the top of the dam, and a height 337 ft above the base, with a superimposed structure on top, about 40 ft high, for housing the gate-hoisting equipment and revolving crane. Each tower is equipped with two welded-steel cylinder gates 32 ft in diameter, one located at the base of the tower and the other 150 ft above, for controlling the flow of water into the penstock. Two towers are located on each side of the river, with bridges between the towers and to the dam. Fig. 3 is a sectional elevation through the penstocks and intake towers.

The two upstream towers divert water into the penstocks placed in the lower tunnels 50 ft in diameter at approximate elevation 650. Each 30-ft steel pipe is to be connected to a cast-steel base embedded in the tower foundation, and to slope downward to a 50-ft tunnel, being embedded in concrete from the tower base to the tangent of the bend in the lower tunnel.

---

[3] See "Hydraulic Valves and Gates for Boulder Dam," by P. A. Kinzie, MECHANICAL ENGINEERING, July, 1934, pp. 387–408.

The two downstream towers divert water into the penstocks placed in the upper 37-ft tunnels at elevation 820. Details of the towers have been described elsewhere.[3] Provision is made for power-operated trashrakes.

The main conduits or headers are 30 ft and 25 ft in diameter. Individual 13-ft penstocks branch off the headers, four from each of the 30-ft sections, to serve fifteen 115,000-hp and two 55,000-hp turbines[4] in the power house. Below the last penstock outlet the headers in each tunnel are reduced from 30 to 25 ft in diameter. The 25-ft headers in the two upper tunnels terminate in six $8^1/_2$-ft conduits leading to as many 84-in. needle valves located in the canyon-wall valve houses. The 25-ft headers in the two lower tunnels will terminate in complicated pipe manifolds embedded in the downstream tunnel plugs. These manifolds consist of three-way wyes branching from the 25-ft straight pipe into three 13-ft curved pipes, each of which again splits into two 86-in. outlets serving a total of six 72-in. needle valves. The valves discharge into the tunnels from which the water flows into the river after its energy is dissipated. All outlet valves will be protected by emergency slide gates to permit shutdowns for inspection and maintenance work on the needle valves.[5]

HYDRAULIC STUDIES

A comprehensive program of hydraulic investigation was carried out by engineers of the Bureau of Reclamation for the purpose of keeping hydraulic losses in the pipe system down to a minimum because of the fact that the power, according to estimates, will have a capitalized value of about $121,500 per constant foot of head. However, considering the fact that losses vary as the square of the velocity, and taking into account all operating factors, this foot of head has an average value of $32,500 based on the contemplated plant output. It was therefore considered good economy to conserve head by improved, even if somewhat costlier, design.

At such times as water is flowing over the spillways or is discharged through the various needle-valve outlets, hydraulic losses have no value as affecting power revenues. Based on the report "Hydrology of the Boulder Cañyon Reservoir," by E. B. Debler, hydraulic engineer of the Bureau of Reclamation, it was determined that 14 per cent of the time water will be spilled or discharged through outlets other than the turbines. Hence, the hydraulic losses are of importance only during the remaining 86 per cent of the time. It was also estimated that firm-power generation will be in effect for 27 per cent of the time, with a load factor of 42 per cent. Firm- and secondary-power production were estimated for 59 per cent of the time, with a load factor of 55 per cent. Proper allowance has been made for these factors in the determination of the value of hydraulic losses.

The high velocities in the pipe, which range up to 44 ft for the 30-ft headers with all needle valves open, and up to 18 ft through the 13-ft penstocks, will produce proportionate hydraulic losses. These can only be reduced by a proper interior coating of the pipe to lower the frictional resistance and by proper design of bends, branch connections, and manifolds.

When it became necessary to evaluate the relative hydraulic efficiencies of bends and branch connections for various designs or proportions, an extensive research was made for reliable information obtained by experiments. With the exception of isolated data found in hydraulic literature, the only extensive experiments uncovered on the subject were those made at the Hydraulic Institute of the Technical College of Munich, Germany.[6] These tests were made under the direction of Professor Thoma, and included the determination of losses in pipe bends, cylindrical branches, and in conical branches of different flare angles and with various angles between the main and the branch. They were carried out with extraordinary care, particularly with regard to the requirements of hydroelectric practise. While these experiments were conducted with small-size tubes (mostly 43 mm in diameter), Professor Thoma justified this on the ground that, for a given form and relative roughness of walls, the losses are not dependent on Q, but only on the value of the Reynolds number, but as the changes within the scope of the higher Reynolds numbers are small, no great error exists if the loss coefficients established for a Reynolds number of 225,000 are used for all higher values.

The loss coefficient is given as a proportion of the velocity head, or $\frac{\text{loss in fitting}}{V^2/2g}$.

A bend or branch outlet in a pipe, as found by the tests, will effect an increase in the frictional resistance of the succeeding straight pipe, and this influence will extend for 20 to 50 diameters. The tests further established the relative losses of rough and smooth walls and the best proportion of R/d for bends with various deflection angles.

The loss coefficients for branch outlets were found to vary in relation to the individual water quantities. The rounding of edges, within limits, reduces the losses of flow into the branch line. Similar tests made in April of this year at the plant of the Bailey Meter Co., Cleveland, Ohio, on a very much larger and carefully constructed model of the 30-ft header with its four penstock outlets appear to confirm the results of Professor Thoma's tests, and indicate that the results secured from his tests can be applied to larger pipes.

Apparently insufficient attention has been paid heretofore to the proper shaping and deflection angles of branch connections, these matters having been left largely to offhand opinion. The tests by Professor Thoma give information for the most economical cone and deflection angle and show clearly the hydraulic advantages of (1) branch connections with deflection angles less than 90 deg, and (2) a conical connection over a cylindrical connection.

Computations based on the tests showed the most favorable flare angle for a conical branch to be from 12 to 14 deg.

As a result of these studies the bends and branch connections were designed in accordance with recommendations quoted, with slight compromises in favor of pipe alignment and fabrication, allowable erection lengths, and weights. All bends were designed with a radius equal to three or four diameters, except where a different radius was necessary for alignment with the tunnel. Bend segments with maximum deflection angles of 10 deg were used. The 13-ft penstocks branch off from the 30-ft headers at an angle of 75 deg, with a terminal outlet opening 14 ft 6 in. in diameter for connection to 13-ft penstocks leading to the 14-ft butterfly valves, and reduce from there to the required diameter for connection to the turbines.

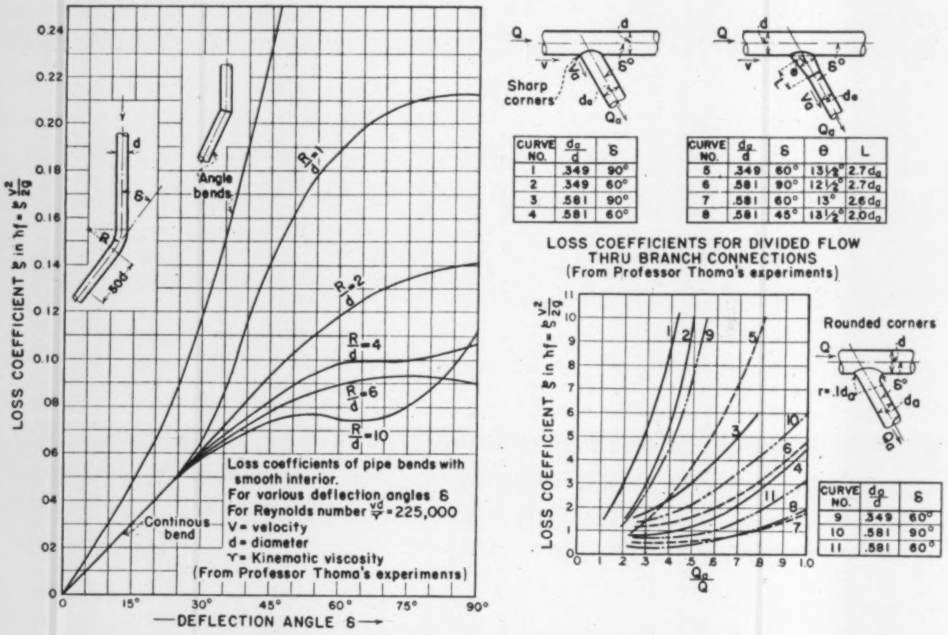
---

[4] See "Turbines for Boulder Dam," by I. A. Winter, MECHANICAL ENGINEERING, vol. 56, July, 1934, pp. 415–425.

[5] The needle valves and slide gates are described in a paper by P. A. Kinzie, presented at the Semi-Annual Meeting, Denver, Colo., June 25 to 28, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, that will be published later.

[6] "Hydraulic Losses in Pipe Fittings." Report on some experiments made by the Technical College of Munich, by Professor Thoma. Translated by F. M. Fernald. Transactions, World Power Conference, 1929, Tokio, Japan, vol. 2, pp. 446–472.

"Experiments to Determine the Loss in Right-Angle Pipe Tees," by Gustav Vogel. Translated by Chas. Voetsch. Mitteilungen der Hydraulischen Instituts der Technischen Hochschule, Munich, vol. 1, Feb., 1926, p. 75.



CURVE NO.	d_a/d	δ
1	.349	90°
2	.349	60°
3	.581	90°
4	.581	60°

CURVE NO.	d_a/d	δ	θ	L
5	.349	60°	13½°	2.7d_a
6	.581	90°	12½°	2.7d_a
7	.581	60°	13°	2.6d_a
8	.581	45°	13½°	2.0d_a

CURVE NO.	d_a/d	δ
9	.349	60°
10	.581	90°
11	.581	60°

FIG. 4 LOSSES IN BENDS AND BRANCH CONNECTIONS

The total discharge capacity at the four conduit systems with the reservoir water surface at elevation 1221 is about 120,000 cfs, assuming that all turbines are operating and that all outlet valves are open. The upper-tunnel conduits have a capacity of approximately 31,000 cfs each and the lower-tunnel conduits approximately 29,000 cfs each. This was arrived at by computing the losses through the intake tower and pipe system in accordance with loss coefficients in bends and branch connections established by the experiments previously mentioned. The friction losses in the straight pipes were calculated by Scobey's formula, $h_f = k_s \frac{V^{1.9}}{D^{1.1}}$, using a friction coefficient k_s for new continuous-interior pipe. Fig. 4 shows diagrams of loss coefficients for various bends and branch connections.

PIPE DESIGN

The power plant will be located at the downstream toe of the dam as shown in Fig. 1, and will consist of two wings, one on each side of the river, with offices, operating and storage rooms, and shops in that portion constructed across the downstream face of the dam. The river face of each wing will be 575 ft long, with a width of 76 ft. Plans provide a maximum rated turbine output of 1,835,000 hp, the machinery for which will be installed by the Government as needed. The initial installation includes four 115,000-hp and one 55,000-hp units, while the final installation will consist of fifteen of the large units and two of the small units. The turbines will operate at a maximum static head of 590 ft and a low head of 420 ft.

All turbines will be provided with relief valves having a capacity of 80 per cent. The pressure rise in the pipe system, due to water hammer caused by gate closure, has been calculated on the basis of a 5-sec closing period. The maximum calculated pressure rise is 37 ft.[7] With reservoir level at elevation 1221 the maximum static head is 584 ft at the center of the pipe. This, combined with the head due to water hammer, was used in calculating the plate thickness of the pipe. In view of the very large diameter it was considered necessary to depart from the usual practise of determining the plate thickness for the pressure head at the center of the pipe. Consequently for 30-ft pipes approximately 17 ft was added to the pressure head at the center line, and a proportional amount for pipes of other diameters.

The allowable pressure P at the center of horizontal pipes, with a radius of r (inches) and for a plate thickness of t was calculated from the formula

$$P = \frac{st}{r} - rW_w - W_s$$

where s = allowable hoop or circumferential stress, lb per sq in.

W_w = weight of one cu in. of water (0.03617 lb)

W_s = weight of one sq in. of shell plate (0.284 lb)

For a pipe slope of α the allowable pressure P may be increased by $0.4335\,r(1 - \cos\alpha)$, with r in feet.

Carbon-steel plates of high strength were developed by the Illinois Steel Co. especially for this project. A minimum yield strength of 38,000 lb per sq in. and a minimum elongation of 12 per cent in eight inches were specified. One tension and one bend specimen are taken from each plate as rolled. The

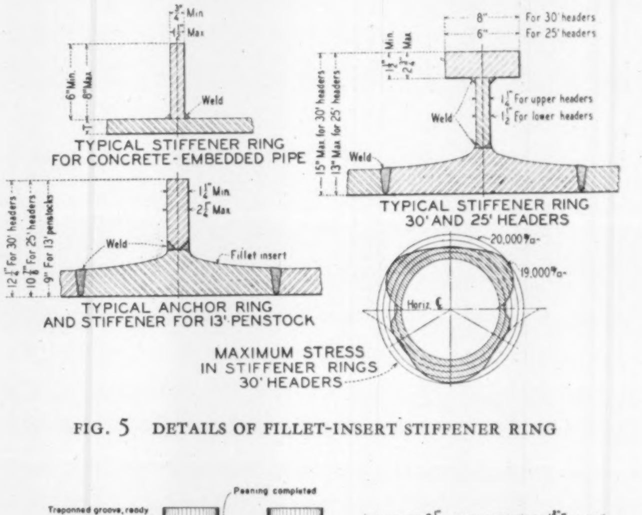
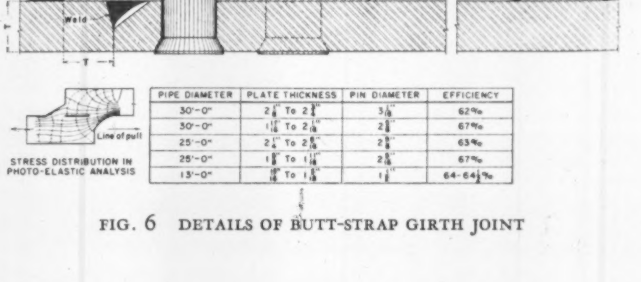

¾"-Min
1"-Max
6"Min.
8"Max
Weld
TYPICAL STIFFENER RING FOR CONCRETE-EMBEDDED PIPE
8" For 30' headers
6" For 25' headers
1¾"-Min
2¼"-Max
1⅝" For upper headers
1½" For lower headers
Weld
15" Max for 30' headers
13" Max for 25' headers
TYPICAL STIFFENER RING 30' AND 25' HEADERS
1⅛"Min
2⅛"Max
12¼" For 30' headers
10⅞" For 25' headers
9" For 13' penstocks
Weld
Fillet insert
TYPICAL ANCHOR RING AND STIFFENER FOR 13' PENSTOCK
20,000#□"
19,000#□"
Horiz. ℄
MAXIMUM STRESS IN STIFFENER RINGS 30' HEADERS

FIG. 5 DETAILS OF FILLET-INSERT STIFFENER RING


Peening completed
Trepanned groove, ready for peening
30°-60° Fillet weld
Weld
T
9⅝"
1¾T
Reinforcing ring
Calking edge
Line of pull
STRESS DISTRIBUTION IN PHOTO-ELASTIC ANALYSIS

PIPE DIAMETER	PLATE THICKNESS	PIN DIAMETER	EFFICIENCY
30'-0"	2⅛" To 2¾"	3 1/16"	62%
30'-0"	1 15/16" To 2 1/16"	2⅝"	67%
25'-0"	2¼" To 2 5/16"	2⅝"	63%
25'-0"	1⅝" To 1 11/16"	2 5/16"	67%
13'-0"	13/16" To 1 5/16"	1½"	64-64½%

FIG. 6 DETAILS OF BUTT-STRAP GIRTH JOINT

physical properties of plates rolled to date have been found to be in excess of the requirements.

---

[7] "Computation of Water-Hammer Pressures in Compound Pipes," by Robert E. Glover. Symposium on Water Hammer, A.S.M.E., 1934.

A design stress of 18,000 lb per sq in. was used, no allowance for corrosion being made. This resulted in plate thicknesses of from $1^{11}/_{16}$ in. to $2^{3}/_{4}$ in. for the 30-ft pipe, from $1^{5}/_{8}$ in. to $2^{5}/_{16}$ in. for the 25-ft pipe, from $^{15}/_{16}$ in. to $1^{5}/_{16}$ in. for the 13-ft pipe, and $^{7}/_{8}$ in. and $^{5}/_{8}$ in. for the 9-ft and $8^{1}/_{2}$-ft pipe, respectively.

The 30-ft pipe sections are being made from three plates, each of which is 130 in. wide for straight pipe sections and has a length of 32 ft. The heaviest plates of $2^{3}/_{4}$ in. thickness will weigh about 41,000 lb each, and two of these will make a carload from the mill to the fabricating plant. The 25-ft pipe sections will be made from two plates and the 13-ft and $8^{1}/_{2}$-ft pipe sections from one plate. Two sections of 30-ft, 25-ft, or 13-ft pipe will be welded together in the shop, with fillet insert stiffener and supporting brackets between, forming erection sections or laying lengths up to 24 ft 9 in. long. Penstock branch-pipe sections 30 by 13 ft, made of $2^{3}/_{4}$-in. plate and with heavy reinforcement as shown in Fig. 12, will weigh approximately 180 tons each, thus taxing the capacity of the 150-ton cableway used for transportation.

The estimated weight per linear foot of plain fabricated pipe is as follows:

30-ft pipe of $2^{3}/_{4}$-in. plate	11,200 lb
25-ft pipe of $2^{5}/_{16}$-in. plate	7,800 lb
13-ft pipe of $1^{1}/_{4}$-in. plate	2,200 lb
9-ft pipe of $^{7}/_{8}$-in. plate	1,100 lb
$8^{1}/_{2}$-ft pipe of $^{5}/_{8}$-in. plate	740 lb

The $8^{1}/_{2}$-ft canyon-wall valve conduits are fabricated in approximately 35-ft erection lengths. They will be concreted into the tunnels and therefore neither stiffeners nor supporting brackets are necessary.

The extraordinary size of the conduits presented an unusually difficult problem in stiffener and support design. (See Fig. 7.) Analytical work of the Bureau of Reclamation confirmed by model tests of the Babcock & Wilcox Co., showed that a saddle type of support would have to be substantially continuous before it could support these pipes with reasonable stresses. This would have been costly and therefore stiffeners and supports were developed in line with the general type described by Herman Schorer.[8] In the discussion of Mr. Schorer's paper it was pointed out by R. E. Glover,[9] engineer of the Bureau of Reclamation, that a more economical design could be secured by taking advantage of the assistance which the stiffener receives from a portion of the pipe shell. It was important to attain such economies in this case because of the magnitude of the stresses in this large-diameter pipe and because of the necessity of reducing the depth of stiffeners and retaining the maximum amount of clearance between them and the tunnel lining. The necessary formulas were worked out by engineers of the Bureau of Reclamation by applying to the problem the mathematical theory of thin cylindrical shells. The calculated stresses and displacements showed good agreement with those obtained from a model section of experimental pipe. The result was a substantial saving in cost.

The restriction placed upon the expansion of the shell near the stiffener ring, when the pipe is under pressure, results in high bending stresses at this point. In order to reduce these stresses to safe limits a special fillet insert was developed. This insert is a rolled-steel section 21 in. wide, of varying thickness, starting with $^{1}/_{8}$ in. above the shell thickness and increasing by 2 in. additional thickness toward the center, where the stiffener ring is welded on. Typical sections showing fillet inserts and stiffener rings are shown in Fig. 5. The shape of the curve for the insert was developed through mathematical work performed by the Bureau of Reclamation and by photoelastic tests made by S. C. Hollister.[10]

A typical support designed for the 30-ft and 25-ft conduits is shown in Fig. 8. The supporting brackets are of welded construction using H-beams and plates of suitable size to carry the pipe and water load for the span to the concrete piers, which are located in the center of each erection length. The brackets are also designed to resist longitudinal bending action resulting from temperature movement of the empty pipe during construction. In order to reduce the effect of the temperature force, transferred to the base of the bracket by sliding friction, two sheets of hard graphited packing will be used between the base of the bracket and the supporting plate on the top of the concrete pier. The brackets are welded to the stiffener ring with suitable reinforcing ribs better to resist the longitudinal bending forces. The web of the stiffener section will be increased in thickness for a length of 6 ft near the reinforcing ribs, for a more efficient transmission of bending stress from the ribs to the fillet insert. The purpose of the eccentric connection between the centroid axes of the stiffener and supporting bracket is to develop a moment to counteract the bending force in the stiffener ring.

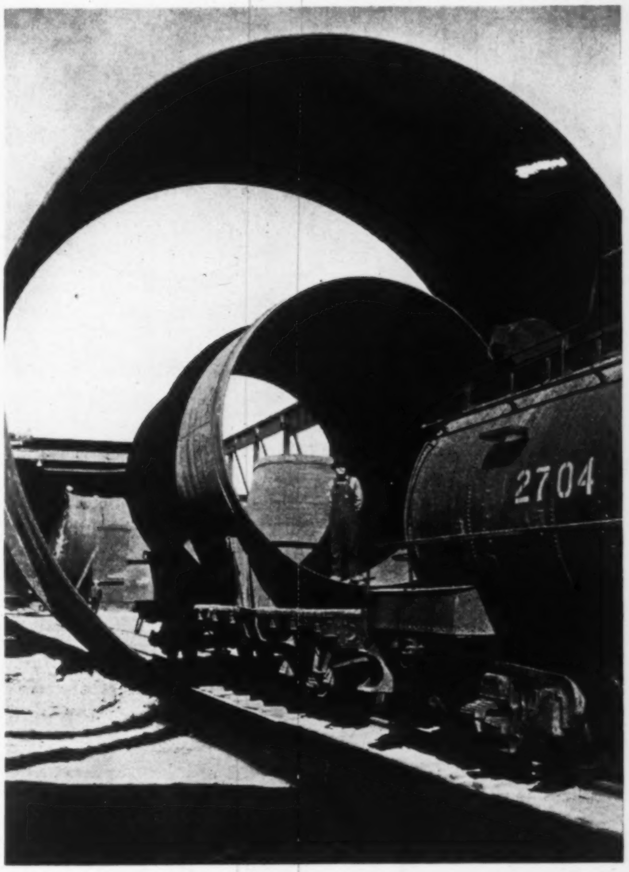


FIG. 7 30-FT PIPE SECTION THROUGH WHICH A LOCOMOTIVE AND CAR LOADED WITH 13-FT PIPE SECTIONS IS PASSING

---

[8] "Design of Large Pipe Lines," by Herman Schorer, Proc. Am. Soc. C.E., September, 1931.

[9] Ibid.

[10] Professor of Structural Engineering, Purdue University, West Lafayette, Ind. Mem. A.S.M.E.

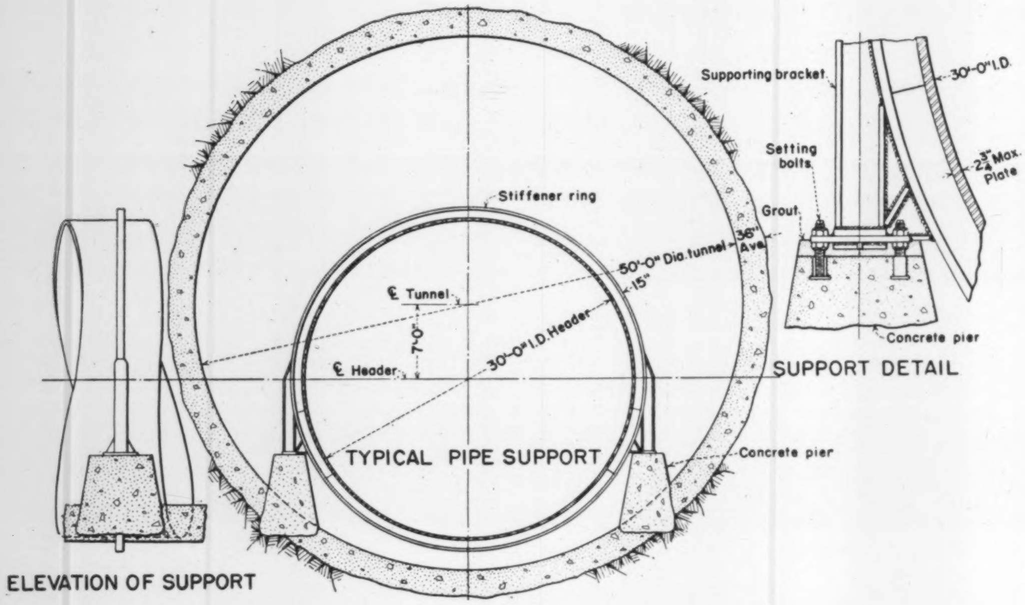


FIG. 8 TYPICAL PIPE SUPPORT FOR 30-FT PIPE IN 50-FT TUNNELS

ERECTION JOINTS

For field connection between the erection lengths of the pipe a special type of welded and riveted girth joint will be used. This joint will eliminate all welding in the tunnels and the necessity of local stress relieving. This is important because of the high temperatures prevailing in the tunnels during the summer months and the difficulty of proper ventilation to maintain normal working temperatures.

The final details of this girth joint were developed by the Babcock & Wilcox Co. in conjunction with photoelastic tests made by Prof. S. C. Hollister to determine the best distribution of longitudinal forces in the joint. Details of the joint are shown in Fig. 6.

A butt strap of the same thickness as the pipe shell is welded to one end of each erection length in the shop, using a double 30–60 deg fillet weld. The open portion of the butt strap will be made a close fit over the adjoining pipe section, to be expanded by heating and shrunk on when erecting the pipe in the tunnel. The holes will be drilled from the solid in the shop and reamed and burnished when aligned in the tunnel for a double row of steel pins. The pins vary in diameter from $1\frac{1}{2}$ in. to $3\frac{1}{16}$ in., according to the plate thickness. They have countersunk heads on the inside of the pipe and on the outside a cylindrical head of the same diameter as the shank. This outer head is undercut with a tapered shank and the butt strap has a groove around each pin hole as shown. The thin ring of metal remaining between the groove and the pin hole is compressed around the tapered part of the shank by the use of a special tool, which forces the countersunk head to a tight seat. All pins are to be ground to a diameter 0.001 in. per inch of diameter larger than the diameter of the hole, producing a force fit. This method produces a girth joint with the machined ends of adjoining pipe sections in as close contact as can be attained, which will be insured by a sufficient amount of tack welding to produce a considerable force by shrinkage when cooled. A joint efficiency of about 100 per cent may be had in compression, while the efficiency in tension, for the various plate thicknesses, is computed to be between 62 and 67 per cent.

The field girth joints for the $\frac{5}{8}$-in. plates of the $8\frac{1}{2}$-ft valve conduits and for the $\frac{7}{8}$-in. plates of the 9-ft penstock branches leading to the two small turbines will be hot-riveted, using the same butt-strap design and $\frac{7}{8}$-in. and $1\frac{1}{8}$-in. rivets, respectively.

The pinned or riveted end of the butt strap is provided with a beveled edge for calking with a blunt-nosed tool. The maximum projection of the pins or rivet heads on the inside of the pipe is $\frac{1}{8}$ in., which produces a pipe of practically

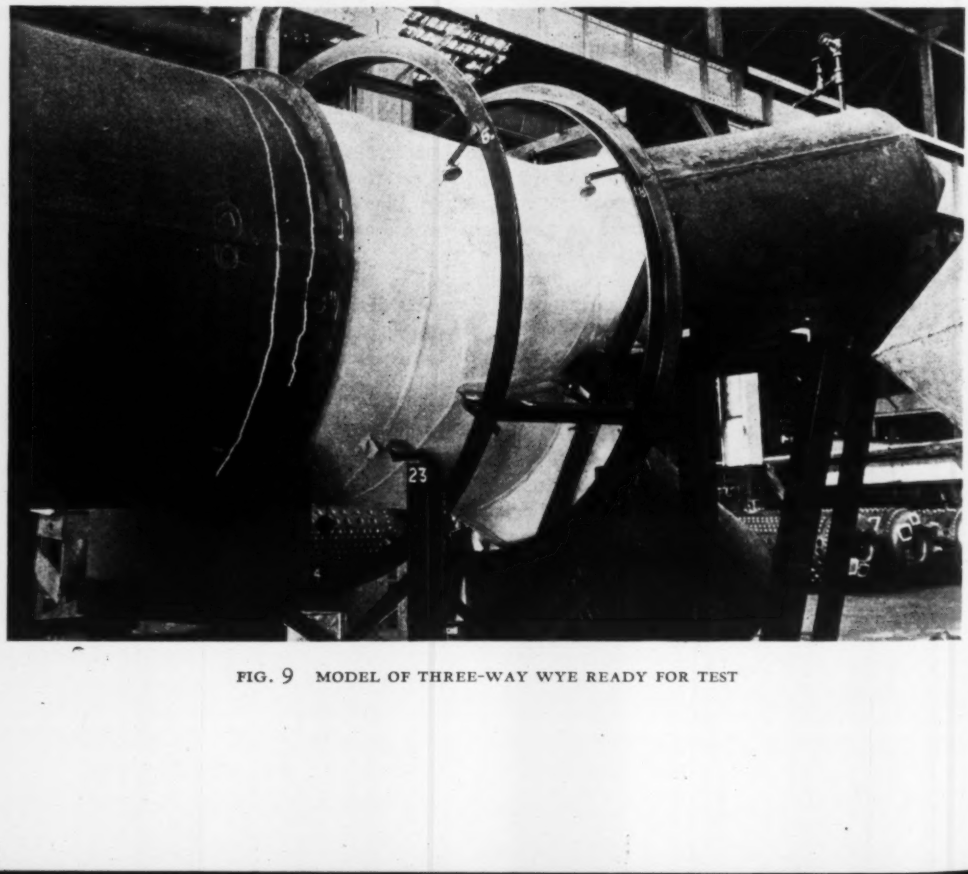


FIG. 9 MODEL OF THREE-WAY WYE READY FOR TEST

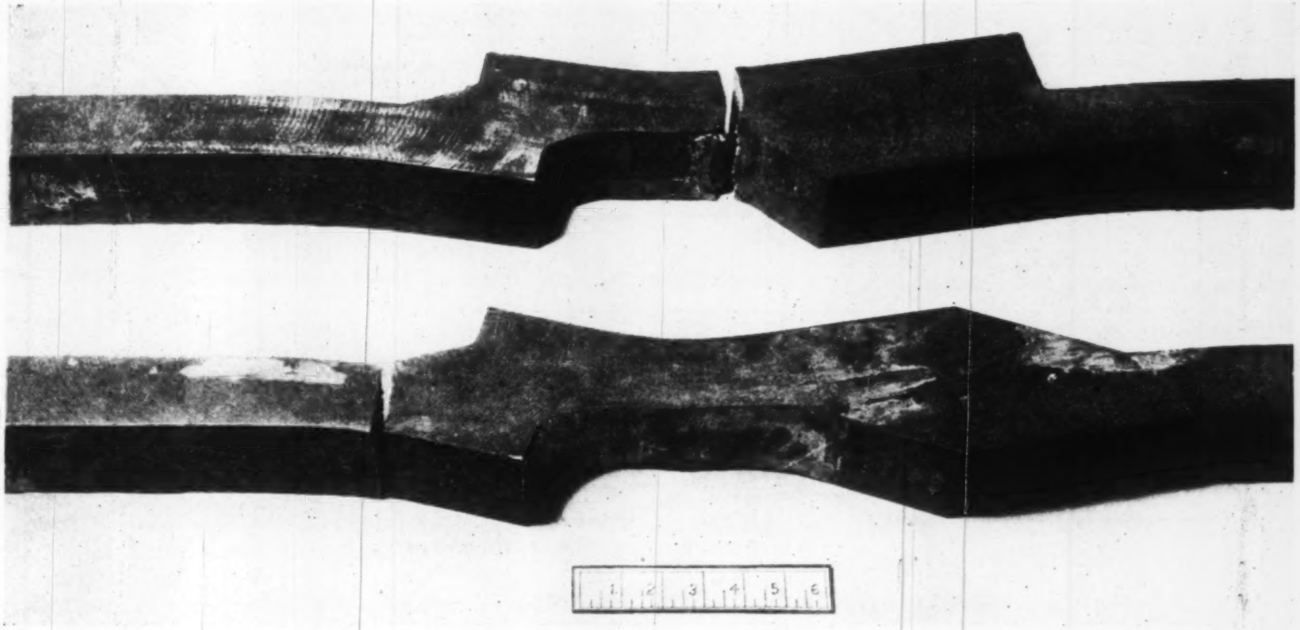


FIG. 10 GIRTH JOINT TEST SPECIMEN, PLATE THICKNESS $2^{3}/_{8}$ IN.

smooth interior. A rectangular bar, or so-called "tire," is welded to the insert end of the pipe, $9^{1}/_{4}$ in. from the calking edge of the butt strap. This tire is provided particularly to resist secondary stress in the pipe shell when under longitudinal tension, its size and location having been determined from tests of models of the pinned girth joint made from full-thickness plates and full-sized pins. It also provides a means for the drawing up of the pipe section into the bell-end or butt strap.

MODELS

Investigations to determine stresses that might occur in the girth joints, branch connections, wyes, and other portions of the penstocks were made at the plant of the Babcock & Wilcox Co. at Barberton, Ohio, under the supervision of Prof. S. C. Hollister, who also supervised photoelastic investigations at Purdue University of the outside butt-strap pinned girth joint and of several other features.

The four principal models were of the branch tee, the three-way wye, and the two-way wye, made to one-sixth scale, and a large model of the girth joint 15 ft in diameter, using plates $2^{3}/_{4}$ in. in thickness, with spherical heads to permit a pressure test to destruction. This occurred in the heads at a pressure of 600 lb per sq in. as shown in Fig. 22. Three models were also made of the pipe shell to one-sixth scale, with stiffener rings and supports, to which various water pressures were applied, and strain-gage stress measurements were made under the various pressures to determine the stresses in the shell and stiffener rings. The three-way and two-way wye models were also tested in a similar manner, followed by pressure application to destruction. Deformations were measured with the pipes half full, just full, then at the various pressures, the maximum being that computed to produce the maximum allowable stress, and again measured with the pipe full but under no pressure, as a check to observe any permanent deformation that might have occurred under pressure. The specifications require that all branch connections and wyes be given a hydrostatic test of $1^{1}/_{2}$ times the working pressure in the shop.

Special attention was given to the action of stiffener rings caused by the weight of the water and the pressure, the magnitude and direction of stresses in the shell, and deformations. A section of the pipe shell between stiffeners was found to be transmitting a radial load, showing that both shear stress and flexure exist. The arrangement of strain gages on the model of the three-way wye is shown in Fig. 9. For pressure effect it was found that the computed points of deformation were in close agreement with measured values. In the models flexural stresses are in combination with endwise stresses, as the ends are closed by heads. This will not occur in the penstock, as closure joints between anchors will be made at low temperature, produced by artificial means if necessary.

As compression exists longitudinally on the outside surface

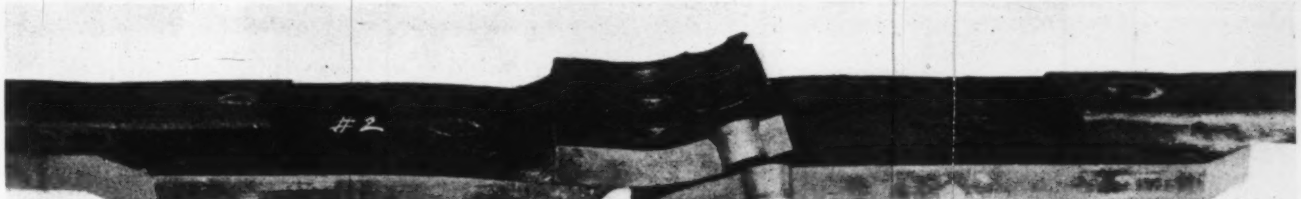


FIG. 11 PINNED-JOINT TEST SPECIMEN, PLATE THICKNESS $2^{3}/_{8}$ IN.

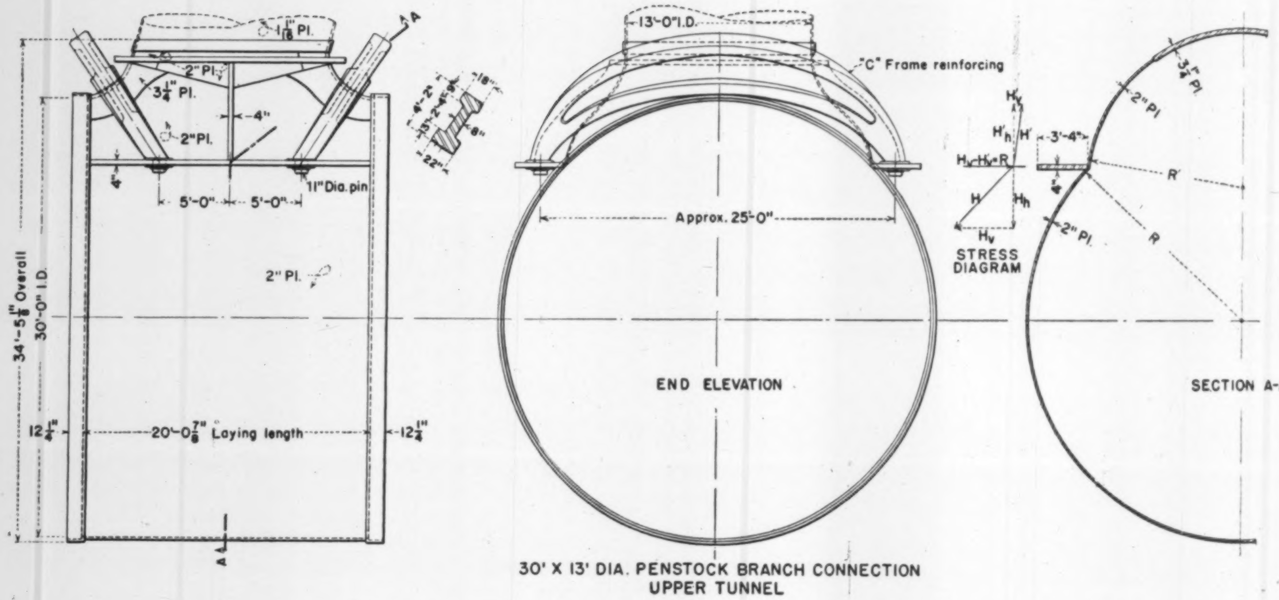

1 1/8" Pl.
2" Pl.
3 1/4" Pl.
2" Pl.
4"
4"
5'-0"
5'-0"
11" Dia. pin
2" Pl.
34'-5 5/8" Overall
30'-0" I.D.
12 1/4"
20'-0 7/8" Laying length
12 1/4"
A
A
13'-0" I.D.
"C" Frame reinforcing
Approx. 25'-0"
END ELEVATION
STRESS DIAGRAM
3'-4"
3/4" Pl.
2" Pl.
2" Pl.
R
R'
SECTION A-A
30' X 13' DIA. PENSTOCK BRANCH CONNECTION
UPPER TUNNEL

FIG. 12 30-FT BY 13-FT BRANCH CONNECTION, STREAMLINED DESIGN

of the shell at the stiffener ring, while hoop stress occurs in the girth direction, it became necessary, with these combined stresses, to increase the area of the critical section, which resulted in the specially rolled shape, or fillet insert, shown in Fig. 5.

PINNED GIRTH JOINTS

The welded portion of the girth joint was determined after photoelastic analyses were made of 20 model forms, which showed that a lap equal to the thickness of the shell plate, with a 30–60 deg weld on the outside, and a curved weld inside, produced the most satisfactory flow of stress from shell to strap. Physical tests of a complete joint, using $2^3/_8$-in. plates, were made to determine strength and deformation. These deformations and stresses shown by the physical tests determined the need for the reinforcing ring near the butt strap. The concentration and flow of stresses are shown in diagram on Fig. 6, and photographs of the test specimen in Figs. 10 and 11.

CONNECTION FOR STATION-SERVICE PENSTOCK

The four separate penstock systems will be interconnected through the 36-in. penstock serving the two 3500-hp station-service turbines. Any penstock system, after a shutdown, can be filled from this service penstock by a manipulation of valves, diverting the water from any filled conduit to the one to be filled. By this method the conduits are being filled from the bottom, which will eliminate the heavy surges to be anticipated when filling them from the top through the cylinder gates in the intake tower.

The station-service penstock will have 30-in. connections to the lower ends of the first four 13-ft penstocks, leading to all upper and lower tunnel headers thereby.

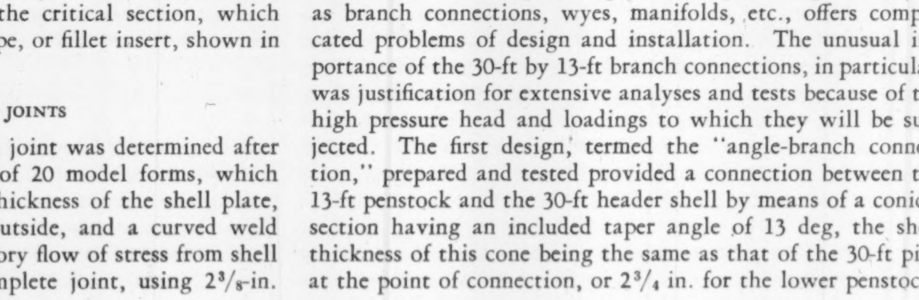

25'-0" crs
8'-6" I.D.
8'-6" I.D.
8'-6" I.D.
8'-6" I.D.
8'-6" I.D.
8'-6" I.D.
5/8" Pl.
5/8" Pl.
16" Valve control header
7/8" Pl.
5/8" Pl.
1 1/8" Pl.
1 1/8" Pl.
14'-0" I.D.
1 1/16" Pl
25'-0" I.D.
20'-0" I.D.
1 3/8" Pl.
2 Way Wye
1 1/16" Pl.
CANYON WALL OUTLET MANIFOLD

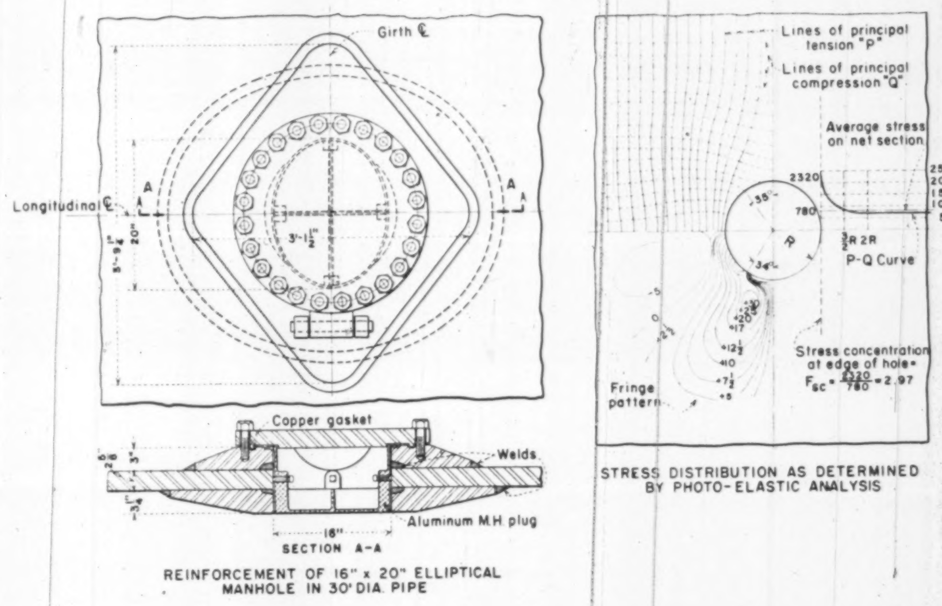
FIG. 13 MANIFOLD—CANYON-WALL OUTLET

DESCRIPTION OF "SPECIALS"

The structural design of "specials" of great magnitude, such as branch connections, wyes, manifolds, etc., offers complicated problems of design and installation. The unusual importance of the 30-ft by 13-ft branch connections, in particular, was justification for extensive analyses and tests because of the high pressure head and loadings to which they will be subjected. The first design, termed the "angle-branch connection," prepared and tested provided a connection between the 13-ft penstock and the 30-ft header shell by means of a conical section having an included taper angle of 13 deg, the shell thickness of this cone being the same as that of the 30-ft pipe at the point of connection, or $2^3/_4$ in. for the lower penstocks and 2 in. for the upper penstocks, the diameter at the point of connection being about 14 ft 6 in. To compensate for the metal removed from the pipe shell a diamond-shaped plate of greater thickness was incorporated, further stiffened by three curved vertical ribs welded to the shell on each side of the cone and perpendicular to the run of the 30-ft pipe. While model tests showed this design to be practically in conformance with the specifications as to stresses, the rib welding cannot be X-rayed to determine if any defects exist, which is a cause for concern.

An improved design has now been developed by the Babcock

& Wilcox Co., shown by Fig. 12, having a streamlined connection with the 13-ft penstock, which is superior hydraulically to the angle-branch design. The stresses are subject to mathematical analysis and all welds can be X-rayed, thus giving assurance of structural adequacy. The concentration of stress at the junction between the radius of the pipe shell and the varying radii of the formed plates around the outlet is carried by horizontal beams extending the full length of the branch. At two mid-points the beams on the top and on the bottom of the branch are connected by a pin 11 in. in diameter to the ends of two massive cast-steel "C" frames which carry that part of the load resulting from the internal pressure that is not taken by hoop tension in the shell of the branch connection.

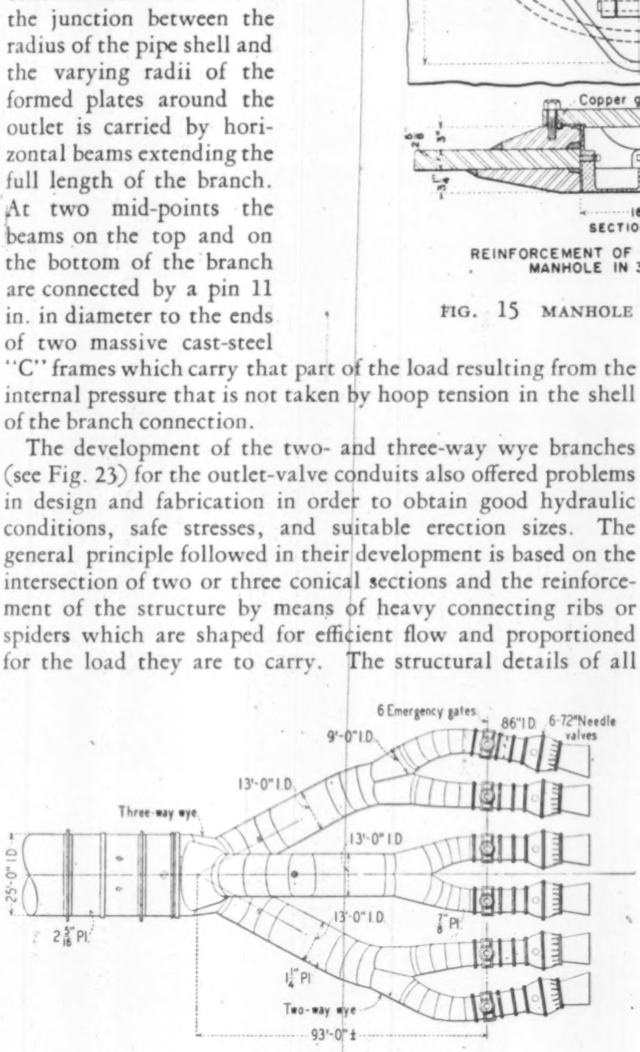


REINFORCEMENT OF 16" x 20" ELLIPTICAL MANHOLE IN 30' DIA. PIPE

STRESS DISTRIBUTION AS DETERMINED BY PHOTO-ELASTIC ANALYSIS

FIG. 15 MANHOLE DESIGN AND STRESSES BY PHOTOELASTIC ANALYSIS

The development of the two- and three-way wye branches (see Fig. 23) for the outlet-valve conduits also offered problems in design and fabrication in order to obtain good hydraulic conditions, safe stresses, and suitable erection sizes. The general principle followed in their development is based on the intersection of two or three conical sections and the reinforcement of the structure by means of heavy connecting ribs or spiders which are shaped for efficient flow and proportioned for the load they are to carry. The structural details of all branch connections and wye branches were developed by the contractor as required in the specifications, and are subject to the approval of the Government.



TUNNEL PLUG OUTLET PIPES

FIG. 14 MANIFOLD—TUNNEL-PLUG OUTLET

Two of the most important and complicated manifold designs in connection with the outlet valves are illustrated in Figs. 13 and 14. Fig. 13 shows the details of the canyon-wall outlet manifold leading to six 84-in. needle valves. These are located in the upper tunnels, one on each side of the canyon. Fig. 14 shows the layout of the tunnel-plug manifold with six end branches connected to as many 72-in. needle-valve outlets. One of these manifolds is located in each lower tunnel.

MANHOLE AND DRAIN OPENINGS

Elaborate investigations were made in an effort to determine the most suitable reinforcement around all openings which will be cut in the pipe shell. The customary method—replacing the metal which has been removed from the pipe shell—was considered rather arbitrary and inadequate for this project.

The method of reinforcement first proposed by engineers of the Bureau of Reclamation consisted of a circular cast-steel or forged-steel disk with the required opening and reinforcing metal, and a smooth interior to suit the curvature of the pipe, to be inserted and butt-welded in the shell. This, from the standpoint of good hydraulic design and transition of stresses from pipe shell to reinforcement, seemed to be as near the ideal as it is possible to attain. The Babcock & Wilcox Co. then made some experiments in welding circular flat plates 24 in. in diameter and $1^5/_8$ in. thick into plates of the same thickness and having an opening 24 in. in diameter. The region around the circular weld was stress-relieved locally by electrical radiant heaters. Strain-gage measurements were taken in the circular plate and in the border of the plate around the weld before and after welding and after stress-relieving. It was found that the effect of welding the rigid circular joint produced severe plastic deformations in the plate near the weld and stresses exceeding yield-point values. After local stress-relieving, the circular weld was X-rayed and no defects were observed in the region of the weld. The evidence obtained shows, however, that in eliminating residual stresses due to welding from the affected area around the weld by local stress-relieving, this will produce a new set of residual stresses. These stress-relieving strains were, in some parts of the affected area, greater than the original residual strains caused by welding.

From the standpoint of welding, therefore, this type of insert-reinforcement around openings was not considered feasible and the problem had to be attacked from another angle. Prof. S. C. Hollister then made an extensive investigation of the subject, which included mathematical work, physical tests on steel plates, and photoelastic analysis performed on flat plates and cylindrical models of pyralin, with reinforced openings. The conclusions drawn from the investigations are that for a cylindrical shell under hoop tension only, the stress concentration at the edge of an opening is greater than that for a similar opening in a flat plate subject to tension in one direction, when the opening is not small in relation to the diameter.

Stress investigations were made of 20' pyralin models of manhole designs in which the concentration of stress at the edges of the hole on the longitudinal axis of the pipe varied from 1.0 to 2.74 times the hoop stress in the pipe shell, thus establishing the most effective location for reinforcement. At a distance equal to the width of the hole along the longitudinal axis of the pipe the stress concentration reduces to zero, and the lines of principal tensile stress appear practically straight and parallel again. A diamond-shaped reinforcing plate was finally selected for the outside and an elliptical reinforcing plate, streamlined with a long tapered edge for better flow, for the inside of the pipe. This produces a symmetrical reinforcement around the pipe shell, as shown in the final design, Fig. 15. The additional hoop stresses caused by the bending in the shell at the end of the reinforced area can only be reduced by reinforcement with a gradually increasing flexural stiffness, which can be had with the diamond-shaped plate. A further improvement in stress distribution is anticipated for the manholes by changing the opening from a circular to an elliptical shape with the major axis placed perpendicular to the pipe axis.

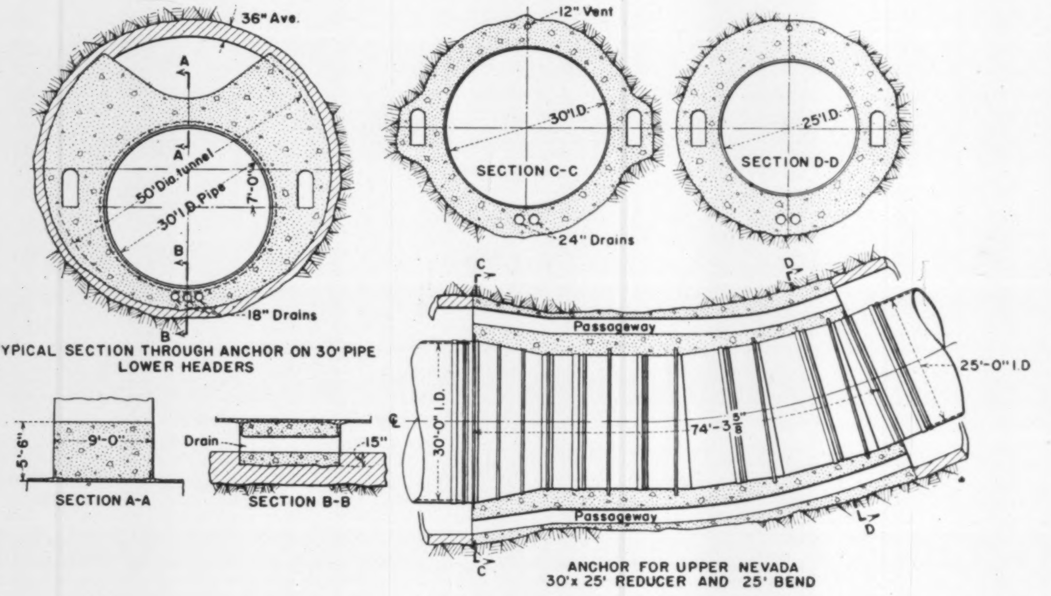


FIG. 16 TYPICAL CONCRETE ANCHORS

In Fig. 15 the two-dimensional stress distribution is shown around a circular opening as obtained by photoelastic analysis on a flat plate of pyralin with a central hole, subjected to tensional stress.

PIERS, ANCHORS, AND THRUST BLOCKS

The 30-ft, 25-ft, and 13-ft pipes are supported on reinforced-concrete piers, one pair of piers being used for each pipe section. Pockets or recesses will be left in the lining of the upper tunnels for all piers, anchors, and thrust blocks. In the lower tunnels, which are being used for diversion purposes first, requiring smooth lining, the necessary pockets and recesses will be chipped from the lining of the tunnel. The piers will be poured up to within 5 or 6 in. of their final height, and tapped steel sockets will be inserted for the setting bolts which will be used to adjust the pipe sections to proper grade by raising or lowering the supporting plate on top of the pier, as shown in Fig. 8. The alignment of the pipe sections can be adjusted by sliding the base of the bracket over the supporting plate, the two sheets of graphited packing between aiding this movement. After the setting of the pipe is completed the supporting plate on top of the piers will be grouted in, and when the final girth-joint connections have been made and no more temperature movements take place in the pipe, the base of the supporting bracket may be welded to the supporting plate.

The piers are designed to resist the overturning tendencies of the empty pipe caused by temperature movements transferred to the supporting plate when the pipe is under construction. They are also proportioned to carry the dead load of pipe and water with a maximum compression on the concrete of 800 lb per sq in.

Each conduit system is anchored at both upstream and downstream ends and around the bends and manifolds. Two intermediate anchors are provided for the headers in the upper tunnels and three for the headers in the lower tunnels. For the 13-ft penstocks two anchors are provided, one around the lower bend near the power house and one near the connection to the 30-ft header. These anchors will be constructed of reinforced concrete, poured into recesses of the tunnel lining, and will be provided with passageways, drain openings, and vents, as shown in Fig. 16. They are designed to take care of unbalanced forces in the pipe due to differences in temperature and cross-sectional area of pipe shell.

In order to take care of the considerable forces at the reducers and shorter bends, it was decided, after considerable study, to embed their entire lengths in concrete. The maximum resultant forces on the anchors will, as a rule, occur with the pipe empty at the assumed maximum temperature of 100 F, which is 50 F above the final erection temperature of the pipe. For a filled pipe the maximum temperature rise was assumed at 30 F. With a pipe of uniform diameter, anchored at both ends, and having a shell of varying cross-sectional area because of changes in plate thickness, the force which the pipe will exert on the anchors due to its tendency of elongation (disregarding friction on supports) is

$$P = \frac{(ctE - \sigma\mu)(L_1 + L_2 + \dots)}{\frac{L_1}{A_1} + \frac{L_2}{A_2} + \dots}$$

where c = coefficient of thermal expansion
t = rise in temperature of pipe shell above final closing temperature of pipe line
E = Young's modulus of elasticity
μ = Poisson's ratio (pipe filled)
σ = hoop stress in pipe shell (pipe filled)
L_1, L_2, etc. = lengths of pipe having cross-sectional areas of A_1, A_2, etc., respectively.

For a pipe line of varying diameter, having reducers, or with bends, the unbalanced forces on the reducers or bends must be considered in addition to the forces resulting from temperature changes. Unbalanced forces as large as 20,000,000 lb were calculated for the upper-tunnel anchors and up to 30,000,000 lb for the lower-tunnel anchors.

Forces resulting from the division in flow at the 30-ft by 13-ft penstock branch connections will be resisted by so-called thrust blocks, one pair at each branch connection. The thrust blocks are also of reinforced-concrete construction, similar to the anchors, except that they are designed to resist lateral instead of longitudinal forces. They are 3 ft wide in the upper tunnels and 4 ft wide in the lower tunnels, while the intermediate anchors vary in width from 5 ft in the straight-pipe sections to 74 ft in the upper Nevada reducer and bend section.

FABRICATION

The large diameter of the greater part of the penstocks made it impossible to fabricate the pipe in the eastern plants of the contractor and move them by rail; therefore the pipes are being fabricated at the contractor's plant at Boulder City, Nev. This is done in suitable erection lengths of accurate dimensions to fit in their allotted places in the conduit system when installed in the tunnels.

The Babcock & Wilcox Co. erected a complete field fabricating plant about $1^1/_2$ miles from the canyon rim. The plant site was selected in a location with sufficient level space for the shop and for the extensive yards necessary for storing the completed pipe sections.

The shop building is a steel-frame and galvanized-steel-covered structure, 85 ft wide and 520 ft long, equipped with three 75-ton overhead traveling cranes for the handling of plates and pipe sections. Two cranes working together can raise and transport a completed 30-ft erection length weighing 150 tons. In accordance with provisions of the contract and subsequent revisions in the alignment and design of the conduit system, the following pipe sizes and aggregate lengths are to be fabricated and installed, within a period of 1975 calendar days from the date of receipt of notice by the contractor to proceed with the work:

Length, ft	Diameter, ft	Thickness, in.
4370	30	$1^{11}/_{16}$–$2^3/_4$
1760	25	$1\ ^5/_8$–$2^5/_{16}$
5550	13	$^{15}/_{16}$–$1^5/_{16}$
100	9	$^7/_8$
1840	$8^1/_2$	$^5/_8$

Besides these straight pipes there are to be fabricated 55 special pieces, consisting of branch connections, straight reducers, reducing bends, and two- and three-way wyes. They range in size from 7 ft 2 in. to 30 ft and in plate thickness from $^7/_8$ in. to $2^3/_4$ in., with plates up to $4^1/_4$ in. in thickness for certain locations in the 30-ft by 13-ft branch connections. Their aggregate length is about 880 ft.

The total estimated weight of the completed pipes and specials is about 41,000 tons.

A total of about 45,000 tons of flat plates comprising about 1000 carloads will be shipped from the Gary mills of the Illinois Steel Co. The plates are unloaded at the contractor's fabricating plant by locomotive crane and stored until needed. In the plant the plates are handled by the 75-ton traveling cranes. Each plate is first laid out and marked to the required size and shape, the edges are then properly planed for welding grooves. This is done with a special edge planer, equipped with a double set of cutters for operation in both directions without loss of motion on the return trip. From the planer the plates are moved to the vertical plate-bending roll where they are shaped into cylindrical form. The set of rolls stands $12^1/_2$ ft high and is considered the most powerful ever built for such purposes. The rolls are driven by a 150-hp motor, have a load capacity of 1750 tons, and can handle all the plate thicknesses and sizes for the 30-ft pipe.

Two 1500-ton presses, working as a unit, are provided to form the special conical sections and to bulldoze the edges of the plates to start them through the bending rolls. There is also a horizontal boring machine large enough to machine the ends of the 30-ft pipe sections, and there are other machines for various operations, most of which were specially designed for this work.

Three rolled plates to make up each 30-ft pipe section are first tack-welded. A structural-steel expanding frame is then inserted in the section to keep the shell in a truly cylindrical shape, the longitudinal joints are completely welded, and such other work done as is required. Two of these sections are then welded to a fillet-insert ring, and an outside butt strap is welded to one end and a reinforcing ring to the other to make up the complete installation section.

WELDING

All welding is done by automatic arc-welding machines so arranged that they can be operated either on the top or inside of the pipe sections. The pipe sections are supported on rollers for rotation to bring the circumferential seams under the arc. An automatic metallic shielded-arc process, with alternating current, is used on this work. The automatic-feed mechanism is susceptible of very close control and provides for continuous operation on each passage of the arc. Heavy flux-coated electrodes are provided in 12-ft lengths with threaded joints to eliminate interruptions for rod changes. Each deposit of weld metal is chipped clean of slag to sound metal, wire brushed, and is then cold-worked by peening before the next deposit of metal is applied.

The repeated application of heat in depositing bead after bead has an annealing effect on the weld which results in a fine-grained and homogeneous metal. It is very essential on this contract to secure a homogeneous weld, fully as strong as the material in the plates, as no allowance was made when calculating the plate thicknesses for a reduction in the strength of the longitudinal joint. Therefore, exclusion of oxygen, producing weakening oxides, and exclusion of nitrogen, tending to induce brittleness, are important while the metal is in a molten stage.

The specifications require one weld-test specimen for each fabricated length of pipe. This is to be of the dimensions specified by, and tested in accordance with, Par. U-68 of the A.S.M.E. Code for Unfired Pressure Vessels. In addition, routine physical tests are made of the deposited weld metal, using standard 0.505-in. test specimens. The properties shown by such tests are considerably in excess of specification requirements. Laboratory tests include the following: One joint tension test, one weld-metal test, one cold-bend test, and a specific-gravity test of weld metal. A very complete laboratory is maintained at the fabricating plant, equipped with a 300,000-lb tension-test machine, an X-ray developing room, and miscellaneous equipment. All testing is under the supervision of government inspectors.

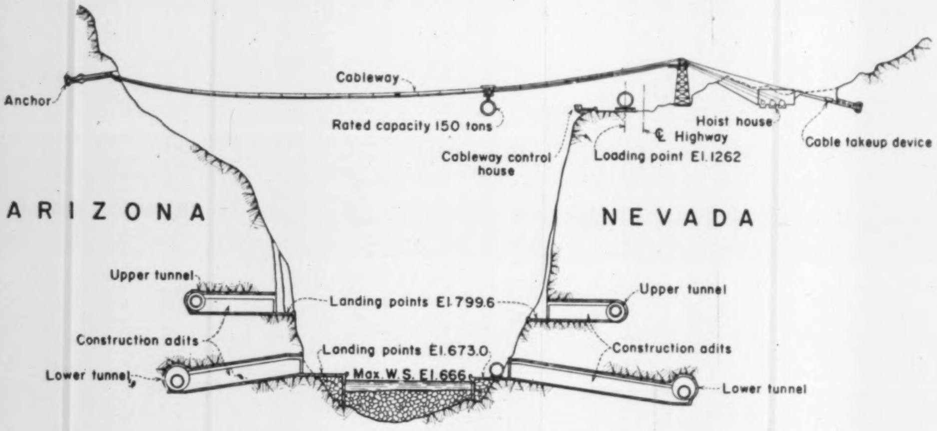


FIG. 17 SECTION SHOWING TUNNELS, ADITS, AND CABLEWAY FOR TRANSPORTING PIPE SECTIONS

All welding is being done in accordance with Par. U-68 of the A.S.M.E. Code for Unfired Pressure Vessels. Defects in longitudinal joints and slag inclusions in girth joints are limited to the allowance prescribed in this code.

X-RAY EXAMINATION

Following the completion of welding every inch of weld is photographed by X-ray to render visible for inspection any internal defects such as blowholes, slag inclusions, or cracks. This contract will require the photographing and checking of more than 400,000 linear feet of welds. The two 300,000-volt X-ray machines are portable and are moved to the welded pipe sections as required. Beginning at a marked point on each longitudinal weld, the machine photographs a 30-in. section of weld and is then moved to the next position, or in the case of a girth weld, the pipe is rotated the equivalent distance.

As soon as the X-ray of a particular weld is completed, the films are developed in the adjacent laboratory and inspected. This is done as promptly as possible to insure approval of the weld before further work has been done on the pipe section. If the X-ray photograph reveals any flaws, that part of the weld is chipped out and rewelded by hand, and again X-rayed. The X-ray can penetrate a steel plate $4^1/_2$ in. thick. In X-raying the $2^3/_4$-in. plates for the 30-ft pipe a sharply focused radiograph can be obtained in 20 sec. The X-ray equipment was developed by the General Electric Co.

STRESS RELIEVING

The specifications require that each pipe section shall be heated uniformly and the temperature increased slowly to from 1100 to 1200 F, held at the soaking temperature for at least one hour per inch of thickness, and then allowed to cool slowly in still air. As an example a 30-ft section made of $1^{15}/_{16}$-in. plate was brought to soaking temperature, 1125 F, in 7 hr, soaked 2 hr, then allowed to cool in the furnace to 650 F in 8 hr, after which the furnace door was partially opened, and further cooling proceeded more rapidly. It is expected that this time cycle can be reduced by several hours. The specially built furnace is the largest of its kind, measuring 36 by 41 ft in plan on the inside, and 28 ft 3 in. high. It adjoins the fabricating plant and is operated as required by the output of the fabricating process. The furnace is heated by an external oil-fired combustion chamber. Means are provided for automatic regulation of the temperature and for the reversal of flow of hot gases at intervals of 1 to 10 min, the usual run being made in a 5-min reversing period. The principle of reversed flow provides for equalization of the temperature of the pipe being treated. The furnace is lined with insulating brick to prevent undue heat losses by radiation and reduce fuel consumption, which is estimated at about 700 gal of oil for a six-hour heating period. Fig. 21 shows a 30-ft pipe section on a car about to be placed in the stress-relieving furnace.

After the pipe section has been found to meet these exacting requirements, the final step is the machining of the ends of the pipe to provide an accurate field fit in the girth joint. This is done with a horizontal boring machine for the large-size pipe sections and with a motor-driven tool held by a spider in the end of the pipe for the $8^1/_2$-ft and 13-ft pipe sections. Fig. 20 shows a bend section of the 30-ft diameter pipe in position on the boring machine of the fabricating plant.

Plant operation and output are dependent upon the work of installation in the penstock tunnels, because of the limited storage space available within reach of the heavy cranes capable of handling the large-size pipe. The smaller pipes can be handled with standard locomotive cranes and stored until needed.

TRANSPORTATION

Transportation of completed pipe sections for the $1^1/_2$ miles from the fabricating plant to the canyon rim is by means of a huge, specially constructed trailer having a pay-load capacity of 200 tons. The trailer is 22 ft in width, 37 ft in length, and has a turning radius of 100 ft. Each of the four corners of the trailer is supported by two axles, each of which carries two rubber-tired wheels. Hydraulic steering is provided for each end by a high-pressure pump, with braking by compressed air. The pump and compressor units with their gas engines are mounted on the outside of the main girders.

CABLEWAY

For lowering pipe sections to the landing platforms at the entrance to the adit to each of the four tunnels a cableway having a rated capacity of 150 tons is provided. It is expected that the maximum loads to be thus transported will be in excess of 175 tons. The span between tower and anchor is 1256 ft. Six main cables are used, $3^1/_2$ in. in diameter and of super-plow-steel lang-lay 6 by 37 construction with hemp center. The carriage conveying speed is 240 fpm, the hoisting and lowering speeds are 120 and 30 fpm, and provisions are made for inching speeds for both conveying and hoisting.

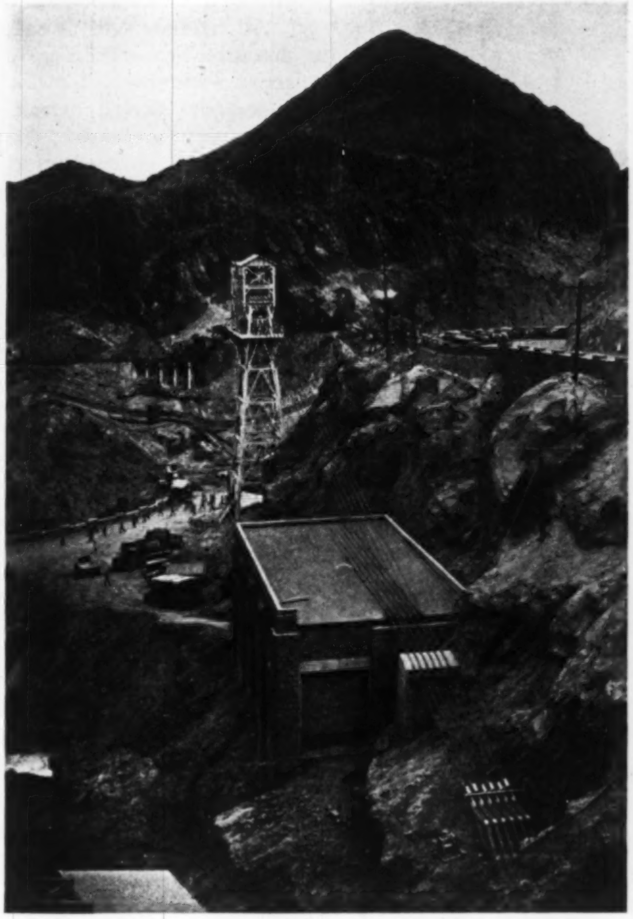


FIG. 18 GENERAL VIEW OF 150-TON CABLEWAY

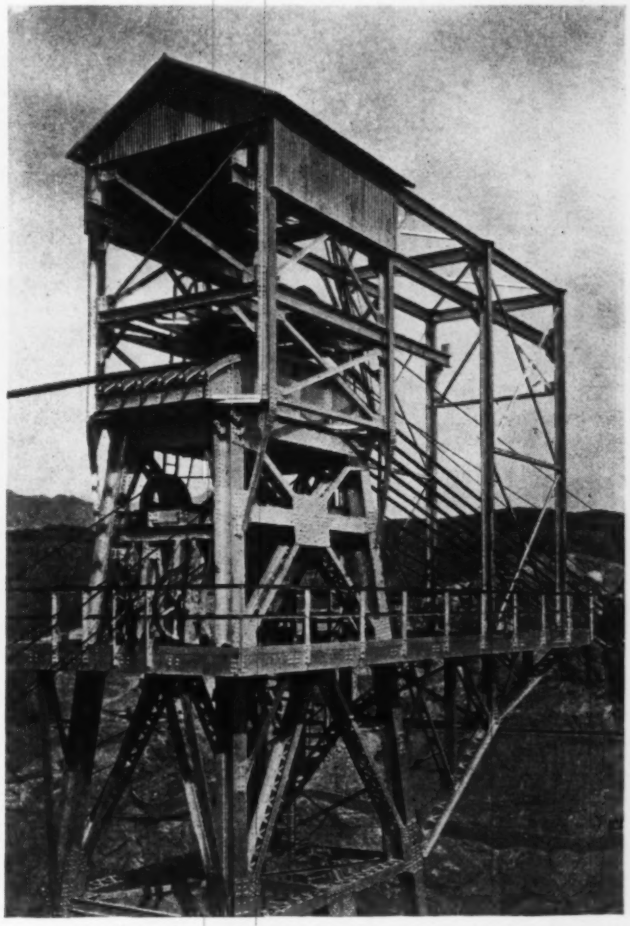


FIG. 19 150-TON CABLEWAY HEAD TOWER

A motor-generator set is used to provide direct current for the hoist motors and Ward Leonard control. The hoisting machinery is located between the head tower and the anchor. Complete control may be had from a control house suspended over the rim of the canyon, also arranged so that control of lowering and hoisting can be transferred to each of the four adit landings. Telephone communication is provided between the main control house and each of the four adit landings, and also to the hoist house. A car of special design will be used to transport sections through the adit where the section is transferred to another special car for transportation in the main tunnels. Hoisting winches will be located inside the intake towers for hauling the car with its pipe-section load up the inclined portion of the tunnels. The winch is placed on a secondary platform which rests on jacks so that when a section is ready to be entered into the butt strap of the connection, the movement will then be made by means of these jacks. Fig. 17 shows a cross-section at the tunnel adits and the elevations of the landings with relation to the cableway. Figs. 18 and 19 are photographs of the cableway and the top of the head tower.

INSTALLATION

Installation of the 30-ft headers will begin at the upper ends of the tunnels at the base of the intake towers. Below the base of the intake towers for the lower penstocks two or three sections of pipe will be placed first and concreted in. This will serve as an anchor during the erection of lower sections, which will progress in a downstream direction to the adits. Installation of the penstocks for the upper tunnels will be continued around the bends, with supports by suitable structural-steel struts, before concreting is started. The installation of the 25-ft headers below the adits will begin at the lower ends of the tunnels, progressing in an upstream direction to the adits. The last pipe section, closing the gap left in the 25-ft conduit, will be located opposite the adit.

The 13-ft penstock sections will be moved through the adits and large tunnels into the 18-ft penstock tunnels, and stored there until ready for final installation starting from the butterfly valves, with a short make-up length for final connection. The $8^1/_2$-ft valve conduits can be transported into the tunnels from the canyon side.

The penstocks are designed without expansion joints, which, on account of size of pipe and head, are not considered feasible. Temperatures at Boulder City range from 95 to 120 F during the summer months. The temperature of the pipe will therefore be much higher during most of the erection period than when filled with water. In order to fix the conduits firmly in position during erection and equalize differences in temperature stress, properly designed reinforced-concrete anchors are provided as previously described. These anchors are placed from 200 to 470 ft apart and during erection one girth joint between each pair of anchors will be left open temporarily. The final pin connection will be drilled, reamed and broached, and completed when the pipe has been cooled down to about 50 F, the low temperature of the water. This cooling may be done either during the winter months, when the temperature drops at times as low as 20 F outside the tunnels, or by artificial

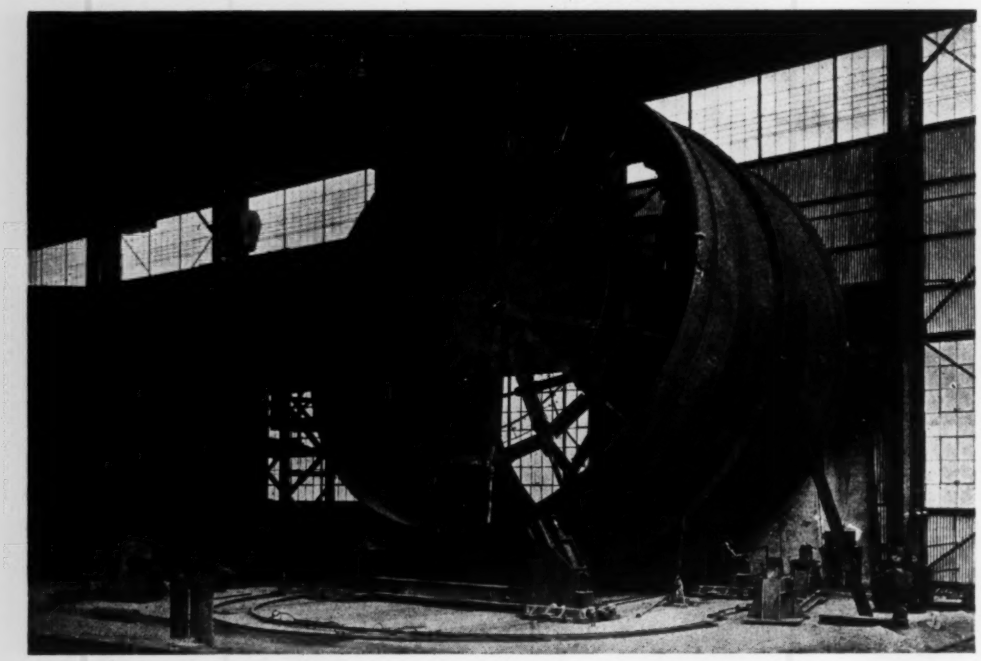


FIG. 20 30-FT PIPE-SECTION STIFFENER FRAMES IN PLACE, SET UP FOR MACHINING AN END WITH SPECIAL HORIZONTAL MILL

means, for which a 900-ton refrigerator plant is available. This will cause expansion in the pipe when filled with water of higher temperature and produce compression. Because of the fact that the pinned type of girth joint is expected to be much more efficient in compression than in tension, expansion in the pipe producing compression will increase both the safety of the joint and its water-tightness.

The final closing girth joints for the 13-ft penstocks are located between the upper anchor and the 30-ft header. The pinned joint here will be completed with the pipe at a temperature of 80 F. The reason for this is that the 30-ft header when under maximum pressure will, according to calculations, expand as much as 0.2 in. in diameter. This expansion would naturally be restrained by the anchored 13-ft pipe, producing excessive secondary bending stresses at the juncture of the branch with the header. The water at a mean temperature of about 60 F, however, produces longitudinal contraction due to the 20 deg drop in temperature from the 80 F closing temperature of the pipe. The water pressure in the pipe will expand its diameter and produce longitudinal tension (Poisson's ratio).

The combined contraction due to temperature change and Poisson's stress approximately balance the increase in the radius of the 30-ft header.

All conduits will be made accessible by manholes for interior inspection and maintenance and by an extensive system of walkways, stairways, and ladders in the tunnels.

For draining the conduits a series of drain openings and valves in the bottom of the pipe will be used. They will drain the water into the tunnels after it is lowered to the lowest possible level by the outlet valves. From the upper tunnels the water is carried by drain pipes to the adit and through a shaft which is sunk to the entrance of the lower-tunnel adit, from which it will drain into the tailrace. For the lower tunnels the water level may likewise be lowered as much as possible by the outlet valves, then by pumps. The last water remaining in the 30-ft header will be drained into the tunnel, flowing thence to a sump near the tunnel plug, from which it is pumped into the tailrace by a vertical pumping unit installed in the needle-valve operating chamber in the tunnel-plug outlet.

All pipe sections will be sandblasted on the inside when completed and painted with one coat of bituminous primer. After installation in the tunnels is completed the inside will be given another coat of bituminous primer and one of bituminous enamel applied hot. The outside will be given one priming

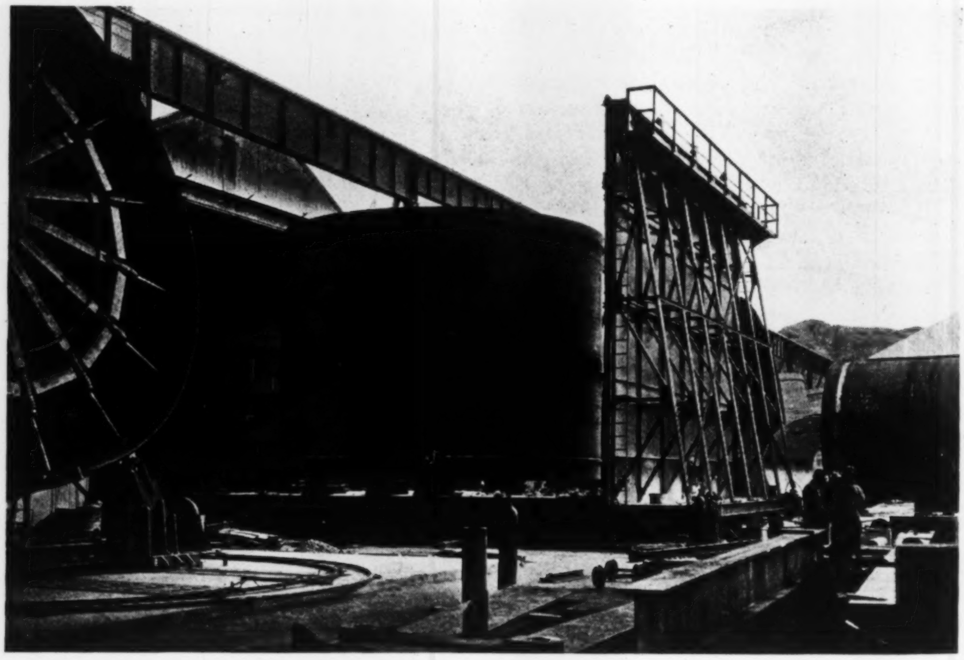


FIG. 21 30-FT PIPE SECTION READY TO ENTER ANNEALING FURNACE coat of red lead and one or two coats of aluminum paint.

The contractor was given notice to proceed on August 10, 1932, and construction of the fabricating plant was started without delay and installation of machinery and equipment was completed, ready for fabrication of the smaller pipes, on April 19, 1933. Fabrication of 30-ft pipe sections was started in August, 1933. The greater part of the 102-in. pipes for the canyon-wall outlet has now been installed. Installation of the 30-ft pipes for the upper penstocks was started on June 10, 1934, and it is expected to have these two penstocks ready for service by September 1, 1935. The lower Nevada penstock is scheduled for completion on Feb. 1, 1936, and the lower Arizona penstock on April 1, 1937.

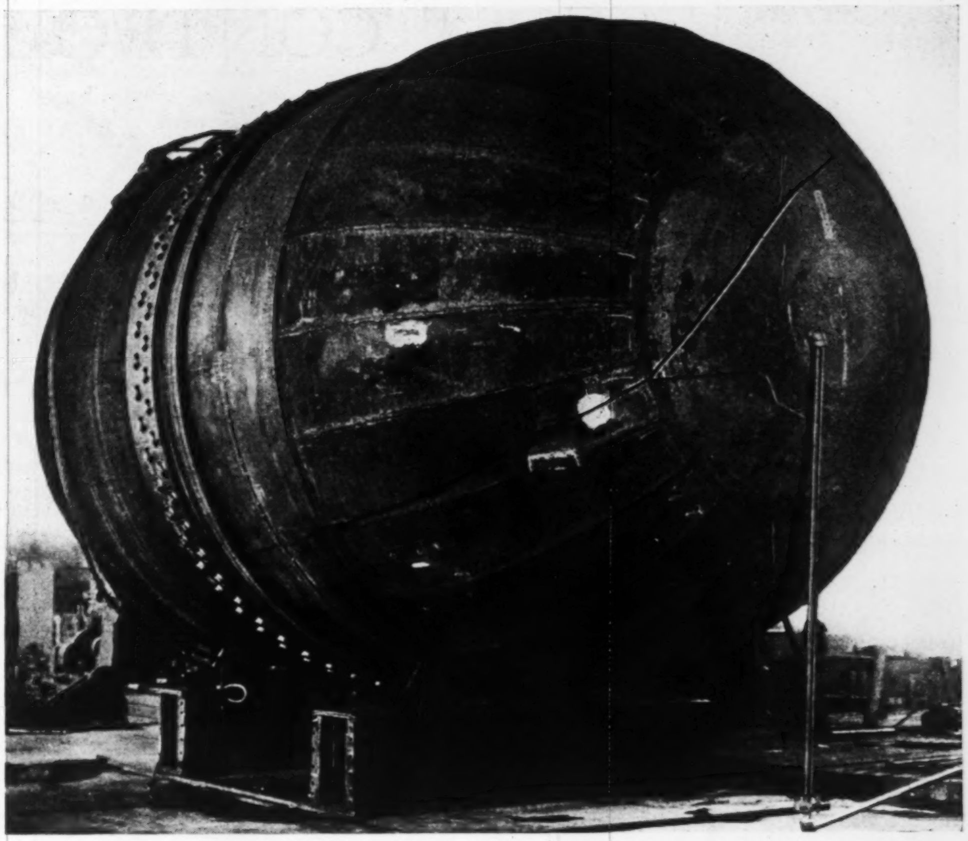
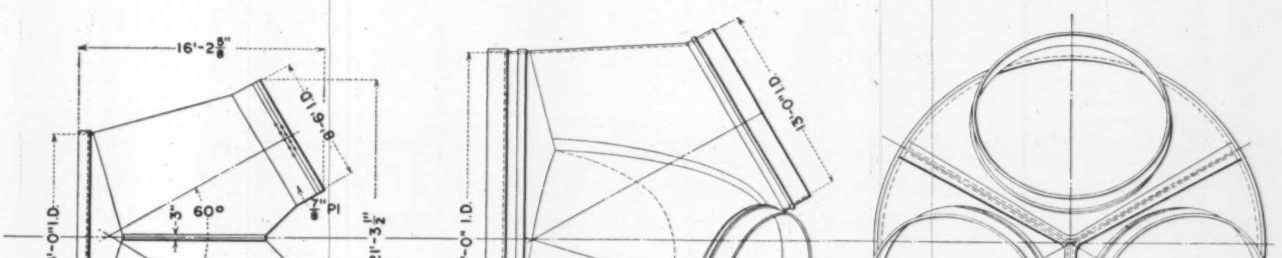


FIG. 22 15-FT MODEL FOR TEST OF GIRTH JOINT WITH $2^3/_4$-IN. PLATE

Several features of the penstocks as described and illustrated herein are believed to be new and novel and patent applications have been issued covering such features. There is much more of interest in connection with mathematical calculations and details of model tests not covered in this article, and it is hoped that a complete report covering these features, with various problems encountered in fabrication and experiences in installation of the large pipes in the tunnels, can be prepared and issued when the penstocks are installed, tested, and put into operation.

Designs of the penstocks were prepared by Peter Bier, engineer, under the direction of C. M. Day, mechanical engineer, U. S. Bureau of Reclamation. All designs and investigations of the Bureau of Reclamation are under the direction of J. L. Savage, chief designing engineer. All engineering and construction work is under the general direction of R. F. Walter, chief engineer, with headquarters at Denver, Colo., and all activities of the Bureau of Reclamation are under the direction of Dr. Elwood Mead, Commissioner, United States Bureau of Reclamation, Washington, D. C.



TWO-WAY WYE 14' DIA. TO 8'-6" DIA.

THREE-WAY WYE 25' DIA. TO 13' DIA.

FIG. 23 TWO-WAY AND THREE-WAY WYES

COST CONTROL

Its Importance Is Emphasized by the Trend of the Times

By L. P. ALFORD[1]

EVERY major shift in human affairs, whether upheaval or subsidence, leaves some enduring change or modification of previously existing conditions. After the event, situations and procedures are not as they were before. As illustrations from business and industry are the following:

(1) The business depression which began in 1893 brought the end of handicraft work in the United States and carried all industry in this country into the factory system.

(2) The unstable industrial conditions of 1913–1914, and of the years of the World War, gave stimulus to the development of production planning and control, which brought those management mechanisms to a high level of excellence and effectiveness.

(3) The short, sharp, business recession of 1921 extended and accelerated the adoption of the principles of mass production and gave new impetus to the efforts to control inventories.

Nearly five years have now passed since the beginning of the panic which broke in 1929. It may not be too soon to explore amid the effects of this major business recession and select out of them any which promise to continue and to have a profound influence upon future industrial operation. Such a consideration indicates one such result in the field of engineering economics which appears to stand out above all others.

MANAGERIAL CONTROL SHIFTING FROM PRODUCTION TO COST

The nature of the economic change which has brought about this effect has been characterized in various ways as, for example, from a deficit to a surplus economy, from a seller's to a buyer's market, from a state of free competition in business and industry to one of cooperative planning. One impact of this change in industrial and business control is the exploration to which this paper is devoted.

Briefly stated, the effect of changed conditions, resulting from the events of the past decade, upon industrial and business control is to shift the essential managerial control from production to cost.

Scientific production control began to be practised by engineers during the 1880's. As a body of principles and as an organized group of procedure, it has had a long and honorable record of development. No outline or summary of this constructive career is called for here. Its high spots and strong points are known to every one who has had any contact with modern industrial management.

Scientific cost control dates its origin some thirty years later. It also has had a distinguished course of evolution from concept to accepted practise. The stages through which it has passed are not so well known as the corresponding steps in the progress of production management.

POSSIBILITIES OF SCIENTIFIC COST CONTROL HAVE BEEN APPRECIATED ONLY RECENTLY

Like production control, scientific cost control as a fundamental idea had an engineering origin. Harrington Emerson gave what is probably the earliest expression to this concept when he stated that all cost systems should provide two columns for cost data, (1) for recording actual costs, and (2) for recording standard costs. In this point of view not only did he differ sharply with most engineers at the time he spoke but he was pointing the way to a revolutionary overturn in cost-accounting procedure. The, then, general attitude of engineers toward cost accounting is shown by the following comments, which are typical: "Employment of an expert accountant to devise and install a cost system in a manufacturing and repairing plant is an absurdity;" and "An expert on shop management can learn the simple accounting required in a short time. In fact he cannot be an expert without this knowledge."

The kind of costs which was in the minds of engineers at that time is what we name today as job-order costs, or historical costs. Taylor believed in costs of this nature, and looked upon a cost system as an adjunct to his methods for securing production control. In a report made to the Bethlehem Steel Company he included the following recommendation as to a cost and accounting system:

> The system should insure an accurate determination of the cost of all goods manufactured by logically and exactly distributing at the end of each month the total expenses of the month, including such items as interest, depreciation, taxes, insurance, as well as of the more direct expenses on to the articles of manufacture which were worked up during the month; and complete, comparative cost statements for all articles completed during the month should be copied from the books on to suitable exhibit sheets and handed over to the proper officers of the company.

Gantt, by his own direct testimony, paid little attention to cost and cost accounting until about 1914. The effect of the business depression of that period apparently forced upon his attention some of the absurdities in current cost finding. With characteristic vigor he caustically wrote:

> The world has suffered from many devastating plagues, but none so destructive as that of the certified public accountant.
>
> Most of the cost systems in use and the theories on which they are based have been devised by accountants for the benefit of financiers whose aim has been to criticize the factory and make it responsible for the shortcomings of the business. In this they have succeeded admirably—largely because the methods used are not so devised as to enable the superintendent to present his side of the case.

The main purpose of the cost-accounting methods of that moment was stated by C. U. Carpenter to be "The possibility of ascertaining the cost of an article is often the only thought in the manufacturer's mind when the cost system is mentioned, and is accordingly the only function that is developed."

STANDARD COSTS FIRST USED IN UNITED STATES IN 1911

These points of view bring out two facts: Engineers had little confidence in, and placed little value upon, the costs compiled by acountants. A few engineers had the imagination to realize the need of new cost methods which would have in them the engineering quality of prediction or predetermination. However, the honor of devising a system of predetermined costs belongs to an accountant, not to an engineer. G. Charter Harrison, who installed the first standard cost system in the United

---

[1] Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

States, had the intensive, thorough training in accounting, theory, and practise of the British chartered accountant. This he supplemented by an extensive experience in the field of general and public accounting in the United States. Influenced largely by Emerson's views on cost, and by the possibility of determining the cost of an article before that cost was accumulated, Harrison installed his first "System of Standard Costs" in the plant of the Boss Manufacturing Company in 1911.

THE FIVE FUNDAMENTALS OF STANDARD COSTS

In this original system were five fundamentals which have persisted and which are now generally accepted both by engineers and cost accountants. These are:

(1) Determination of proper cost before the article, goods, or service are produced.

(2) Recognition of the fact that variations from standard costs will inevitably arise in practise.

(3) Analytical procedure to be applied to these variations to determine their causes.

(4) Application of the management law of exceptions.

(5) Application of the management law of operating rates.

The first of these fundamentals deals with the cost-predetermination function. William B. Ferguson has emphasized the way in which a standard cost can be established:

> In the art of estimating, it is only in determining what costs should be, if we eliminate preventable waste [or using Mr. Emerson's term, it is only in predetermining costs], that we establish a standard which is "a criterion of excellence." In estimating what costs will actually be, we use for a standard of comparison the type or example of past performance which represents the average cost of work under standard conditions. By thus using a standard estimate for each unit (whether the unit chosen be an object or operation), based on the cost of a standard number of units under certain conditions taken as standards, the estimator can proceed methodically to classify and study all cost data and estimates with reference to such standards.

Another engineer, Benjamin A. Franklin, has brought out the second fundamental, the fact that the variation in a cost is the important point in its consideration:

> This variation of the cost of the same article at different times constitutes the important point, not only in the proper understanding but in the appreciation of costs. The ability to master this point and to figure estimates or prediction of cost from a standard under varying conditions gages the comprehension of the meaning and value of practical costs.

Analytical procedure, the third fundamental, can be brought down to a basis of asking and answering pertinent questions, or can be set up in the form of simple formulas. The methods of analysis for the cost of machine idleness and man idleness developed by Gantt are excellent examples of the first method. Harrison's cost and profit variation formulas are the latter.

No law of management is more widely accepted than the one dealing with the exceptions. This is the fourth fundamental and is stated as:

> Managerial efficiency is greatly increased by concentrating managerial attention solely upon those executive matters which are variations from routine, plan, or standard.[2]

This was a favorite principle with both Taylor and Gantt. It is applied directly to costing when only the variations from standards are brought to the attention of the major executives for appropriate action.

Standard costs as developed by Harrison set up standards for the material, labor, and overhead expense for each item of product or service. These standards, therefore, are rates of input and are closely analogous to time rates. It is self-evident that if the input of the cost factors can be controlled, the final cost can be predetermined. The law of operating rates, the fifth and last fundamental, indicates that this is the most direct means of control:

> Operating performance is controlled most directly through control of the rates of expenditure of labor, materials, and expense. (Alford and Hannum.)

The principal steps in the procedure for setting standard costs for an item of product are: (1) Fix the standard quantities of materials, taking them from the engineering bills of material; (2) Determine standard labor costs, setting them from standard times for doing the work and standard wage rates, or from piece rates; and (3) Compute standard burden costs on some basis that will allocate a fair amount of overhead expense to the item. These three costs when summed give the standard cost for the item of product, which can then be authoritatively established.

After the actual costs are accumulated it is certain that variations from the standard will occur. These are then analyzed as to causes. The principal causes of cost variations are those that result from calendar variations, idle time, productivity efficiency changes, labor-rate variations, labor-time variations, material price changes, material consumption changes, number of set-ups, time for making set-ups, variations in distributive expenses, variations in miscellaneous expenses, variations in rates of salaries paid, and variations in personnel of salaried staff.

LITERATURE OF STANDARD COSTS

Mention has been made of the fact that the first installation of standard costs was made by G. Charter Harrison. It is interesting to note that much of the literature on the development of standard costs systems flows back to this origin. Harrison himself has written two books, "Cost Accounting to Aid Production" and "Standard Costs." The engineering approach to the subject, which determined the treatment of costs in the first volume, is sufficiently indicated by the title. The late C. F. Sanders, who wrote the section on cost accounting in "Management's Handbook," was controller of a concern where Harrison installed one of his cost systems. The section on cost-variation formulas in this same handbook was written by Harrison. Two of his former associates, H. Jack Bock and Eric A. Camman, contributed to the cost sections of the "Accountant's Handbook," and Harrison and Bock similarly to the corresponding sections of the "Cost and Production Handbook." Camman, furthermore, is the author of the most recent book on this subject under the title, "Basic Standard Costs."

ENGINEERING FEATURES OF STANDARD COSTS ARE IMPORTANT

As to the extent of the application of this attack upon costs, it has been applied to all kinds of industries, intermittent, continuous, and mixed. In every case the engineering features of the installation are of major importance. The so-called prerequisites to standard costs, which include standard bills of materials and standard times, are of necessity engineering determinations. The method by which the standard costs are set, the installation of the system as a whole, the accompanying variation analyses, and the final method of reporting, are more particularly accounting phases.

Not all of the installations have been satisfactory. The principal reasons for the failures are lacks of understanding and ex-

(*Continued on page 469*)

---

[2] "Laws of Management Applied to Manufacturing," by L. P. Alford, p. 74.

MANUFACTURING TECHNIQUE *of the* UNITED STATES

By R. E. W. HARRISON[1]

THE RELATIVELY satisfactory standard of living attained in this country prior to 1929, and the favor which our manufactured products found in the markets of foreign buyers can be directly attributed to a high degree of manufacturing technique. This technique was a product of the requirements of a receptive and prosperous domestic market, ample and accessible supplies of raw material, and a people whose temperament has always been naturally industrious and constructively inventive. At all times when confronted by problems of great difficulty it is wise to do a certain amount of stocktaking, and with this thought in mind it is in order to take time out for a philosophical review of those factors which built up our country and to question critically whether these same factors exist today with the same degree of efficiency and margin of superiority they formerly possessed.

World events during the past ten years have not by any means been confined to great political issues. The kaleidoscope of world trade has been vigorously shaken up many times during this period, and it provides an interesting study in economics to take a few leading commodities and carefully weigh their relative competitive positions as compared with the positions they occupied, say, in 1924.

While it is not for a minute intended to paint a gloomy picture, it is readily admitted by all those who have the best interests of the country at heart that there has never been any place for false optimism.

There is today a more searching and pressing need for a cold-blooded national stocktaking than there ever was before. The great potential world market for manufactured goods still exists, but other countries, under the stress of adversity induced by the World War and their own internal disorders, have produced manufactured goods which in economic attractiveness are now competing with our own. Therefore, in terms of what we like to think of as our built-in assets, let us see where we stand. Let us honestly ask ourselves the question: Are these assets as good, better, or worse than they were in 1924?

IS OUR MANUFACTURING TECHNIQUE STILL SUPERIOR TO THAT OF OTHER NATIONS?

Take first of all manufacturing technique. Do we still possess that wide margin of superiority in manufacturing technique? Manufactured goods attained their high quality and relatively low cost in the United States as a result of mass-production methods, mass production in turn being induced by a large market with a high power of absorption, and the need on the part of the manufacturers to use large masses of relatively low-priced, unskilled labor. Out of this combination was born the production engineer, an individual unique and peculiar to the United States.

A desire to face the facts compels us to acknowledge that since the peak demands of 1929 most of our production machinery and a large proportion of our production engineers have been idle. The machinery has not been improved at the former high rate and we have been denied the actual practise which is the grist-mill out of which all really useful production ideas are evolved.

We still have great natural resources, geographical homogeneity, and accessibility to raw materials, masses of workers, and, I hope, a desire to work, as well as the inventive ingenuity of our production engineers.

HAS THE TEMPER OF OUR PEOPLE CHANGED?

The next question is: Do we still possess the temperamental advantages which characterized our efforts in 1924? That this temperament has changed even the most casual observer must agree. The voters who put the present Administration into power were motivated by thoughts which had no place in the mental makeup of the voters of 1924. In 1924 the great mass of the workers accepted our then existing industrial leadership without question. There were no questions in their minds at that time regarding the disparity in the distribution of wealth, the curtailment of production to enhance prices, the shortening of working hours to spread employment. At that time they might have been likened to an army of regimented individualists; today the individualism is not so apparent and the objectives are different.

IS THERE A SHORTAGE IN PRODUCTION SKILL?

Consider next our investment in production skill. As is well known, the average manufacturing concern after a number of years of successful operation has an accumulated investment in the productive skill of its executives and key men which in many cases equals its investment in physical or real properties. The same applies to nations; and the desire to look the facts in the face compels us to take into account the disturbing experiences of certain leading industries. A recent up-turn in business brought their operations up to 50 per cent of capacity and compelled them to acknowledge that one of their biggest problems was the provision of sufficient skilled labor to man their machines and processes. Skilled labor is chiefly centered in the durable-goods industries in normal times, and these are the industries which have suffered the greatest during the depression. On the debit side of the balance sheet we are, therefore, forced to the conclusion that there is a serious shortage in skilled labor.

The attention which has been given by this Administration to reforestation might well be extended to deal with this problem of the shortage of skilled labor. Normally, there are two main sources of supply—apprenticeship and immigration. During the rush of business of the last peak, manufacturers in general withheld the long-time investment which a well-thought-out apprenticeship scheme would have provided. Moreover, the national policy in respect to immigration has been such that we could not, and cannot, look to this means of replenishing our stock of skilled workers.

HOW CAN OUR SUPERIORITY IN MANUFACTURING BE RESTORED?

The next task is to consider what may be done to restore quickly and permanently that margin of superiority in manufacturing technique which will permit us to maintain and improve our living standard, and at the same time meet world competition in foreign trade successfully.

---

[1] Chief, Machinery and Agricultural Implements Division, Department of Commerce, Washington, D. C. Mem. A.S.M.E.

First, production specialists must be intensively trained. Countries in competition with ours have even gone to the extent of establishing institutions for production engineers, technical societies and other bodies devoting their energies to the improvement of manufacturing technique. We might do likewise.

Our technical societies could, with advantage, include in their professional divisions one devoted to the interests of the production engineer. Technical journals might take up the cause of apprenticeship and lead their readers' thoughts into channels of constructive activity along these lines.

Above all, we need a plan of action—not necessarily a 5-year plan, or a 10-year plan, but a goal toward which we all can work. Before this goal can be set a critical and philosophical survey of all our productive elements is required, and an evaluation must be placed on it which will let us know what margin we enjoy, if any, in relation to world competition. Such a survey might be made by the Research and Planning Division of the NRA, the United States Chamber of Commerce, or the Department of Commerce. But irrespective of which organization undertakes this work the fact remains that, industry by industry, some one should stand off at one side, weigh up the position, and chart the course.

ROLES OF RESEARCH AND STANDARDIZATION

A discussion of this subject would not be complete without reference to two of the most useful tools which lie at our hands, i.e., basic research and intensive standardization. With the latter carried out along national lines and enthusiastically adhered to, we have the most effective means of cheapening our products without sacrifice of quality. More important, however, is the fact that this will, in turn, enable us to free our creative energies and provide the time and opportunity to devise the newer and broader things we need if we are to lead the way in world development.

If ever there was a time when we needed to make an investment in research, that time is now, for there is much new thought at work in the world field. The Japanese contributions to basic research have amazed those who are acquainted with them; the Russians are devoting much money, time, and effort in this direction; and the older industrial nations, England, Germany, France, and Italy, are very much alive to the fact that in this activity they have an economic weapon which is second to none, enabling them to maintain and improve their relative positions.

A study of the machinery and agricultural-implement industries indicates that the products of England and Germany more nearly equal our own, individually and in bulk, than ever before in the history of these industries. A review of world trade also indicates that these countries have a greater proportion of their manufacturing resources at work than we have. They are conserving and building up their skill, and, furthermore, they are not faced as we are now with strikes, industrial disturbances, and lack of coordination between the views of their employers and workers as we are at the present time.

In the United States workers are paid relatively higher wages and work shorter hours than is the case in other countries. A protective tariff alone is a poor buttress for these privileges. The real buttress is superiority in manufacturing technique. Hence, the workers, as compared with their employers, should have just as great or even a greater stake in the establishment of a national program of rehabilitation.

Cost Control

(*Continued from page 467*)

perience on the part of those who have put in the systems. These insufficiences are: A lack of accounting knowledge on the part of engineers; a lack of experience in the design of methods and procedure on the part of industrial accountants; and a lack of understanding of industrial operation on the part of public accountants. A frequently repeated allegation against standard costs is that the clerical costs of operating the system are very high. Experience shows, however, that such a system when properly designed can be operated at a smaller cost than is required for any other recognized cost system. The reason why it is the cheapest to operate is because it is based on the principle of exceptions.

THE IMPORTANCE OF COSTS HAS BEEN STRONGLY EMPHASIZED RECENTLY BY NRA CODES

It is not likely that at any previous moment in American industrial history has there been so much concern over the matter of costs as there is today. A major reason for this situation is found in the cost provisions of the various industrial Codes of Fair Practise. Many different approaches to the cost problem are set up in these codes, and expressions such as "reasonable cost" and "allowable cost" are introduced. Some require that the code authority shall set up a cost formula for its industry, others that a uniform cost system shall be adopted. The effect of these various code requirements is to intensify the problem of determining industrial costs and as a corollary the control of cost in any particular concern.

Under such conditions it becomes imperative not only to have an accurate knowledge of actual costs but to know when, where, and why variations from those costs arise, and arrange to take proper action to keep all the factors of cost under control. Beyond all this it is recognized that an accurate knowledge of cost is the beginning of policy determination, adequate procedures for budgeting, sales planning, and the overall control of business. That is, all of these management procedures should properly not only be interwoven and interlocked, but be built up from the sure foundation of accurate, known costs.

Dependable costs are now seen to be essential in the solution of many sales problems, such as determination of the profit margin, planning the profit program, scientific setting of selling prices, determining the profit realization point, and developing a salesman's incentive plan. Fewer applications have been made in this field than to the problems of manufacturing operation, but the possibilities of improvement are quite as important.

This situation, viewed as a whole, is a decided departure from the immediate past. Up to the coming of the depression of 1929 the major element in industrial control was production through quantities. The change which has taken place, and which promises to be permanent, is a control of costs, through control of the rates of input of the various cost factors. This change appears to be of major significance and of a permanent character. It is one of the economic results of the depression which promises to be to the advantage of all who are engaged in industrial operation. Hitherto, many unfair trade practises have been attributed to an inexact or incomplete knowledge of cost. Now that a better understanding of cost procedure is imperative, in fact, demanded under many industrial codes, and more precise costs are in the making, the inescapable step is to use this information when it is secured as the basis of improved industrial control.

CONTROL *of* PRODUCTION *in a* DYNAMIC ECONOMY

By E. DILLON SMITH[1]

THE theory of, and the basic method for, the analysis and control of the output of productive industries in the immediate future were presented in a paper entitled "Dynamical Production Analysis."[2] In the present paper the general subject of dynamic production is developed and expanded. The precise methods for the determination of the probable productive tendency of the enterprise and its band of operation control are presented. The points discussed are (1) the determination of the secular trend of the industry, and (2) the establishment of the band of probable variation of future production. Examples will be given to illustrate the application of the methods.

DECADE TRENDS

The technique of fitting an exponential equation to a decade series of data will be considered first. The equation is

$$y = ab^x \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where the growth rate is $r = b - 1$. Consider the data shown in Fig. 1 for the production of automobiles from 1915 through 1925, a decade where the number of observations n is 11. Since time is linear and the production series is approximately a geometrical progression,[3] an exponential equation is the only one suitable to describe the series. If the weighted mean of the progression is computed the weighted mean of the x distribution of the series is established. In other words, we desire to know the balancing point of the area under the progression in Fig. 1, as indicated by the arrow, and then the parameters of the exponential Equation [1] will be selected so that it will enclose the same area and have the same mean as the observed data. Computation of the mean is from the equation

$$\Sigma xy/\Sigma y = m \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

where m is also the first moment of the series. The calculation of the mean is simpler after writing it in the form

$$m = s_2/s_1 \ldots\ldots\ldots\ldots\ldots\ldots [3]$$

where s_1 is the first cumulative sum of the data and s_2 is the second cumulative sum of the serial data of s_1 less the end cumulate. The data for the automobile production of Fig. 1 are given in Table 1, which illustrates the technique of obtaining these statistics of the successive cumulative sums (on an adding machine). It should be noted that the last item in the second cumulation is not used. Equation [3] gives the mean value

$$m = \frac{167{,}726}{26{,}468} = 6.3369$$

TABLE 1 AUTOMOBILE PRODUCTION AND SUCCESSIVE CUMULATIVE SUMS, 1915–1925

Year	Production (thousands)	s_1	s_2
1915	970	26,468	. . .
1916	1618	25,498	167,726
1917	1874	23,880	142,228
1918	1171	22,006	118,348
1919	1934	20,835	96,342
1920	2227	18,901	75,507
1921	1682	16,674	56,606
1922	2646	14,992	39,932
1923	4180	12,346	24,940
1924	3738	8,166	12,594
1925	4428	4,428	4,428

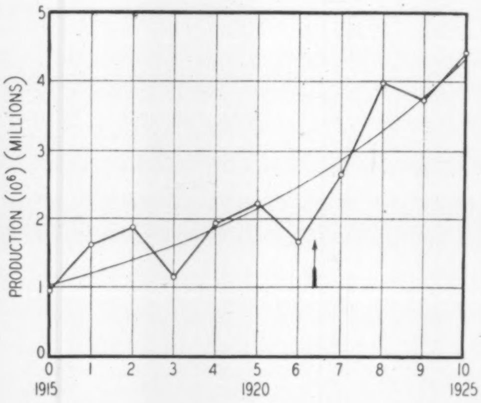


FIG. 1 AUTOMOBILE PRODUCTION, 1915–1925 (0–10) AND EXPONENTIAL-DECADE-TREND LINE

The equation of the mean value can also be written

$$m = \frac{n}{1 - b^{-n}} - \frac{1}{1 - b^{-1}} \ldots\ldots\ldots\ldots [4]$$

Since for decade fits of the exponential equation $n = 11$, it is possible to express Equation [4] as a curve shown in Fig. 2. In the case of the present example, by entering Fig. 2 with the mean value of $m = 6.34$ a growth rate of $r = 15$ is found.

The statistic a in [1] can now be obtained directly from the equation

$$a = \frac{b - (n - m)(b - 1)}{n} s_1 \ldots\ldots\ldots\ldots [5]$$

where s_1 is the statistic associated with Equation [3]. The ap-

---

[1] University Fellow, Columbia University, New York, N. Y.

[2] MECHANICAL ENGINEERING, vol. 56, no. 6, June, 1934, pp. 331–336.

[3] "Geometrical progression" is used to describe a discrete series and an "exponential equation" to describe a continuous one.

Contributed by the Management Division and presented at the Annual Meeting, New York, N. Y., December 4 to 8, 1933, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. The paper has been revised and is published in two sections, the first of which appeared in the June issue.

The many aspects of modern economic life cannot be adequately stated by any single principle. Hence any dynamic theory of economics, from the economist's viewpoint, cannot be singularly stated. A dynamic economy means the change, and the relation and interrelation of events, with respect to other happenings in a connected series of events. The necessity of this approach results from an attempt to integrate the system of which we are a part.

plication of this equation to the example of Fig. 1 and Table 1 gives

$$a = \frac{1.15 - (11 - 6.34)(1.15 - 1)}{11} 26{,}468{,}000 = 1{,}082{,}000$$

These statistics then yield the exponential equation

$$y = (1{,}082{,}000)(1.15)^x$$

where the origin is at 1915. Fig. 1 shows the decade trend line as determined by this equation.

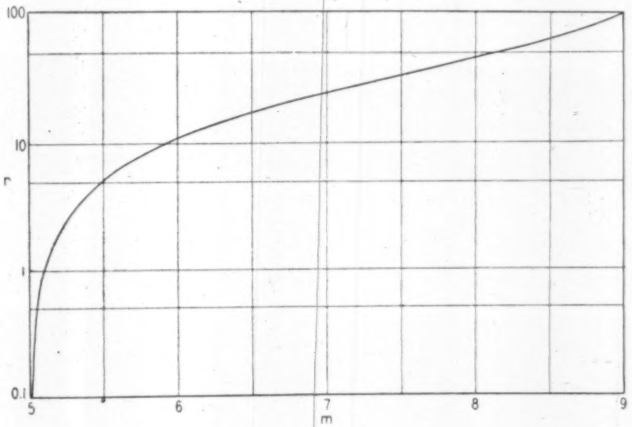


FIG. 2 MEAN-VALUE CHART ($n = 11$)

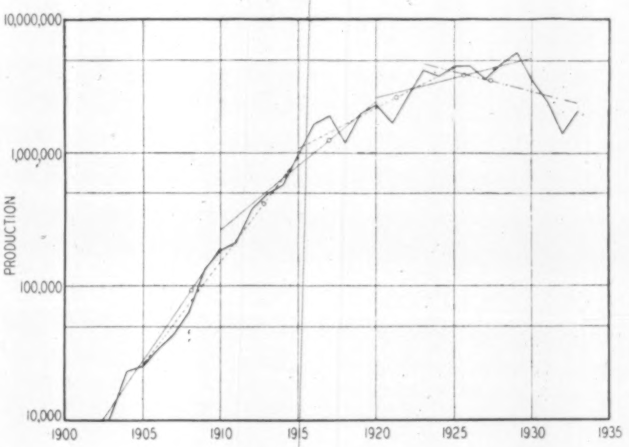


FIG. 4 AUTOMOBILE PRODUCTION, 1900–1933; WITH DECADE TREND LINES AND DECADE MEAN VALUES PLOTTED ON SEMI-LOGARITHMIC PAPER

This method of securing the parameters of the exponential equation accomplishes the summation process after the first term of the serial data is assumed to be the origin. The method is satisfactory for data increasing with an increase in x. A note of caution is necessary, however, when the data decrease with an increase of x. The manner of computing the mean value of a decaying growth rate is the reverse of that used for a positive growth rate. This reversely computed growth rate is then converted to a positive growth rate commensurate with the increasing epochal value of x. This conversion is accomplished by the equation.

$$\frac{1}{1 + r'} - 1 = r \ldots\ldots\ldots\ldots\ldots\ldots [6]$$

where r is expressed in ratio form. This means that a straight line with a given positive slope on semi-logarithmic or ratio paper has been plotted with a negative equivalent slope and expressed mathematically.

By way of example, the data of automobile production for the decade 1923–1933 are summed as indicated and give the mean value

$$m = \frac{226{,}286}{40{,}094} = 5.66$$

In the case of this example the summation process is started with the production figure of 1923 and continued through 1933. This is the reverse of the previous example because the magnitudes of the production data are decreasing with epochal increases. With the mean value that has been determined, Fig. 2 is entered as before and the percentage growth rate is found to be -6.9: in ratio form it is -0.069 or 0.931. Equation [6] converts this statistic to one commensurate with the advancing epochs, e.g.,

$$\frac{1}{1 + 0.069} - 1 = 0.065$$

On a percentage basis $r = -6.5$. This is negative because the sense of Equation [6] is negative. From Equation [5] the statistic a equals 4,650,000. Then

$$y = (4{,}650{,}000)(0.935)^x$$

is the decade exponential equation of the trend line fitted to the 1923–1933 automobile-production data with the origin at 1923.

Fig. 3 is used to facilitate the conversion of reversely computed growth rates to growth rates of the advancing epochs. It is based on Equation [6]. In the case of the example cited the left-hand column of Fig. 3 is entered at $r' = -6.9$ and r is found to be -6.5 (the negative sign is not shown).

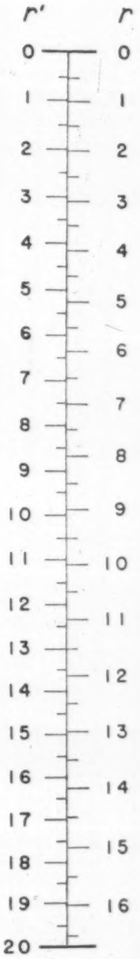


FIG. 3

SECULAR TRENDS

If the decade trend lines of the data are calculated in the manner shown and are then plotted on semi-logarithmic or ratio paper, there will result throughout the secular series of the data a group of straight lines with different slopes. By way of example, Fig. 4 shows the whole series of data for automobile production with the exponentially fitted decade trend lines moved forward five years at a time. (The growth rates were given in Table 2 of the previous article, Mechanical Engineering, June, 1934, p. 336.) If Fig. 4 were plotted on natural paper a whole series of scalloped decade trend lines would result. When a smoothed secular trend line is drawn through these fitted decade trend lines on either type of paper, but preferably the semi-logarithmic, several possible solutions are presented. To remove this confusion the mean value associated with each decade equation is plotted on its respective trend line, as shown by the circles in Fig. 4. If a smooth curve is drawn empirically through these points a very good quasi-mathematical determination of the secular trend line of the data is secured. No useless work has been done because the growth rates of the decades are desired for determining the deceleration of the series. This secular trend line is a close approximation to a fitted polynomial and not as difficult to determine. Unless some simple method is developed for fitting polynomials to data there seems to be no reason for their use, except for special cases.[4] The decade and secular trend lines and growth rates have been determined. There now remains the determination of the acceleration or deceleration in the series from these statistics.

DECELERATIONS

The underlying tendency of the change taking place in the economy is shown by recording the shift in the growth rates from time to time. This tendency is shown graphically on semi-logarithmic paper as the epochal change in the slope of the trend line. A mathematical description of this change is desired so that one production series can be compared directly with another. One way of determining this deceleration (or acceleration) is to fit an exponential equation to the several growth rates. This is equivalent to determining the growth rate of the decade growth rates that have been moved forward quinquennially. This technique is presented in the example of automobile production from 1900 to 1930. Table 2 of the present article shows the determination of the cumulates from the decade growth rates that were given in Table 2 of the previous article.[5] The summation is in a direction opposite to that of the previous example. The end of the serial data on which the summation is begun is determined by that end of the data which has the greater magnitude. If the summation is against the epochs the resulting growth rate is directly applicable to the data, but if the summation process is with the advancing epochs, as in this and the example associated with Equation [6], the growth rates are negative and must be converted to a growth rate commensurate to the advancing epochs, as has been shown. From Table 2 the mean value is

TABLE 2 DECELERATION IN AUTOMOBILE PRODUCTION

Decade	$b = r + 1$	s_1	s_2
1900–10	1.489	1.489	1.489
1905–15	1.428	2.917	4.406
1910–20	1.255	4.172	8.578
1915–25	1.150	5.322	13.900
1920–30	1.071	6.393	....

$$m = \frac{13.900}{6.393} = 2.174$$

From Equation [4], $r_5 = 9.1$ or $b_5 = 1.091$, without regard to sign. It becomes necessary to reduce this statistic to an annual basis; e.g.,

$$\log_{10} b_1 = \frac{\log_{10} b_5}{z_5} \quad \text{.....................} \quad [7]$$

$$= \frac{\log 1.091}{5} = 0.007565$$

or

$$b_1 = 1.0176$$

Since b has been computed in a reverse manner, Equation [6] gives

$$\frac{1}{1.0176} - 1 = (-)0.0173$$

as the desired value of r, as does also Fig. 3. That is, the deceleration is 1.73 per cent per year per year.[6]

Other interpretations of the exponential equation are possible but seem of little value to the immediate problem.[7] Four sigficant items of production series have been determined: (1) the decade trend, (2) the secular trend, (3) the growth rate, and (4) the deceleration. The next problem is the investigation of the production fluctuations about the central-tendency trend line.

PRODUCTION VARIABILITY

The growth-rate and deceleration statistics of a production series have been computed on a percentage basis in such a manner that several different epochs in one industry or one epoch of several industries are directly comparable. In such a comparison, however, one series might fluctuate about its trend line more than another, and at the same time have equal growth rates and decelerations. It would therefore seem desirable to know this fluctuation or the variability about the trend line. Such a statistic can be expressed as the index of variability, the index of instability, or the mean percentage deviation about the fitted trend line. The equation of the percentage of variability is

$$\frac{\Sigma|(y - y_0)/y_0|}{n} 100 = V \quad \text{.............} \quad [8]$$

where y is the observed item at any epoch, y_0 is the corresponding mean epochal value computed from the fitted trend line, and n is the number of observations in the serial data.[8] In this form the V's of different series are directly comparable and suitable for combination. The use of the index of variability seems quite obvious and therefore it needs only to be mentioned that the more stable and regular the growth the smaller will be the statistic V.

Oftentimes a new series of data is derived from two series of primary data. Suppose the trend of the production of automobiles and the population growth are known and it is desired to know the trend of cars produced per capita. Having determined separately the constants of the two primary equations, we compute

$$a_3 = a_1/a_2 \quad \text{.......................} \quad [9]$$

and

$$b_3 = b_1/b_2 \quad \text{.......................} \quad [10]$$

as the parameters of the desired equation. With Equations [9] and [10], therefore, it will be seen that it is possible to secure the new series with little effort, the utility of which is obvious.

DERIVED SECULAR TRENDS

As previously shown, it is essential to know the trend of the growth rates and accelerations; i.e., to obtain the first and second differential of the secular trend line. Computation effort has prevented the use of a polynomial equation to describe the secular trend, which, if of a degree high enough, would, on differentiation, give the desired function.[9] Graphical methods are resorted too in this paper to obtain the proper curves; i.e., successive tangent points of the curve are plotted to secure the curve of the next lower order.

The idea of using a non-refracting reflected image for the location and determination of the tangent is utilized to obtain the successive measures of the desired growth-rate curve. This is again differentiated in the same manner to secure the second lower order or acceleration trend line. A superior method to that of a mirrored ruler is an isosceles prism as an aid in securing the normal line at the tangent point. If the abscissas of this tangent line are always assumed as unity, the ordinate can be read directly and plotted in terms of the desired function at that tangent point.

---

[4] A new method of investigating any series of data is that of orthogonal polynomials.

[5] Loc. cit.

[6] Drop the negative sign when the statistic is denoted a deceleration.

[7] "Adjustment for the Moments of J-Shaped Curves," by W. P. Elderton, *Biometrika*, vol. 25, 1933, pp. 179–180.

"Note on Mr. Palin Elderton's Corrections to the Moments of J-Curves," by K. Pearson, Loc. cit., pp. 180–184.

[8] The vertical lines in Equation [8] signify the absolute value; i.e., the sign of the operation is considered positive.

[9] This difficulty is not present when orthogonal polynomials are used.

Fig. 5 illustrates the technique of graphical differentiation by the mirror and prism methods. Rather than draw normals to the cotangent line the notations of the reflected line at the point of tangency have been reversed, as shown, giving the desired differential Δy at point x.

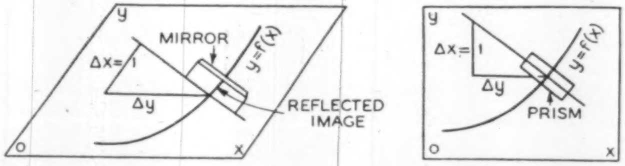


FIG. 5 GRAPHIC DIFFERENTIATION BY MIRROR AND PRISM

BANDS OF OPERATION

In the operation of any industrial enterprise a certain chance variation in production can be expected. The establishment of a control band of operation enabling the management to focus attention on events not directly attributed to chance occurrences would act as a warning indicative of a need for further investigation into the cause of the impacting force affecting the business. These bands of operation are most conveniently set up for the growth-rate and acceleration functions.

Assume the 1920–1930 series for automobile production given in Table 3 and calculate the first and second differences of the observations. These differences are the growth-rate and acceleration variations Δ^1 and Δ^2 respectively. For example, in 1920 and 1921, $\Delta^1_{1920.5} = 1682 - 2227 = -545$; while $\Delta^2_{1921} = \Delta^1_{1921.5} - \Delta^1_{1920.5} = 964 - (-545) = 1509$, and so on. It is important to pay close attention to the sign of the computed difference, which can be checked graphically. Table 3 gives the complete series of the first and second differences.

TABLE 3 AUTOMOBILE PRODUCTION AND DERIVED VARIATIONS, 1920–1930

Year	Production (thousands)	Growth rate Δ^1 (thousands)	Acceleration Δ^2 (thousands)
1920	2227		....
		—545	
1921	1682		1509
		964	
1922	2646		570
		1534	
1923	4180		—1976
		—442	
1924	3738		1132
		690	
1925	4428		—612
		78	
1926	4506		—1004
		—926	
1927	3580		1947
		1021	
1928	4601		0
		1021	
1929	5622		—3133
		—2112	
1930	3510		....

The mean will give a central tendency of the range of the data being studied; i.e.,

$$M_\Delta = \Sigma Y/n \ldots\ldots\ldots\ldots\ldots\ldots [11]$$

Then from Table 3, for Δ^1

$$M_1 = \frac{1283}{10} = 128.3$$

and for Δ^2

$$M_2 = \frac{-1567}{9} = -174.111$$

A band of operation is now established from a knowledge of the derived series for the production of automobiles as it varies about the central-tendency trend line, or, in the case of the immediate illustration, the variation about the mean for the short range of data.[10] That is, we want to know the root-mean-square or standard deviation of the observed data—the square root of the arithmetic mean of the squares of the observations. It is most convenient to write the desired equation as

$$\sigma_\Delta = \left(\frac{\Sigma(\Delta)^2 - (\Sigma\Delta)M_\Delta}{n-1}\right)^{\frac{1}{2}} \ldots\ldots\ldots\ldots [12]$$

Again, making use of the data in Table 3, for Δ^1

$$\sigma_1 = \left(\frac{11{,}659{,}927 - 164{,}608.9}{9}\right)^{\frac{1}{2}} = 1130.16,$$

and for Δ^2

$$\sigma_2 = \left(\frac{22{,}777{,}039 - 272{,}831.9}{8}\right)^{\frac{1}{2}} = 1677.17$$

The interpretation of these statistics is that the standard deviation marks off a distance from the mean, *plus or minus*, within which 0.6826894 of the data will be located, as will the expected observations, provided, however, the new data are recorded under the same conditions that have been investigated. In another way, the chances are about 2.16 to 1 that the observations will fall within this computed band of operation or production control. The analysis of variance of the series would throw further light on the problem, but cannot be treated here.[11]

Fig. 6 illustrates these techniques for the whole production series of automobiles from 1900 to 1934. The growth-rate and acceleration-secular-trend lines have been obtained by graphical differentiation. The variation of the production has been calculated by successive differences. The control bands of production are based on an appropriate standard deviation—calculated for the period 1910–1928.

If it is desired to establish the bands of production in such a manner that 50 per cent of the data will fall within the band and the other 50 per cent outside it, write

$$p = 0.6744898\,\sigma \ldots\ldots\ldots\ldots\ldots [13]$$

as the transformation formula, where p is denoted the probable error. In other words, the chance that the observation will fall within or without the band is now 1 to 1, or even. In the case of the foregoing example, $p_1 = 762.280$ and $p_2 = 1131.235$. The common use of the probable error is its only recommendation, and the reader can establish his control bands at that range if he so desires and interpret the results according to the probabilities mentioned.

---

[10] It is assumed that the frequency of the derived variations in time follows a normal distribution. The results of actual investigation of the distribution in several samples warrants this assumption.

[11] "Calculation and Interpretation of Analysis of Variance and Covariance," by G. W. Snedecor, Collegiate Press, Ames, Iowa, 1934. "Statistical Methods for Research Workers," by R. A. Fisher, Oliver and Boyd, London.

Generally speaking, the bands of operation control should be calculated from time to time to adjust for changes in the economy. These data are then plotted and smoothed by suitable graphical methods.

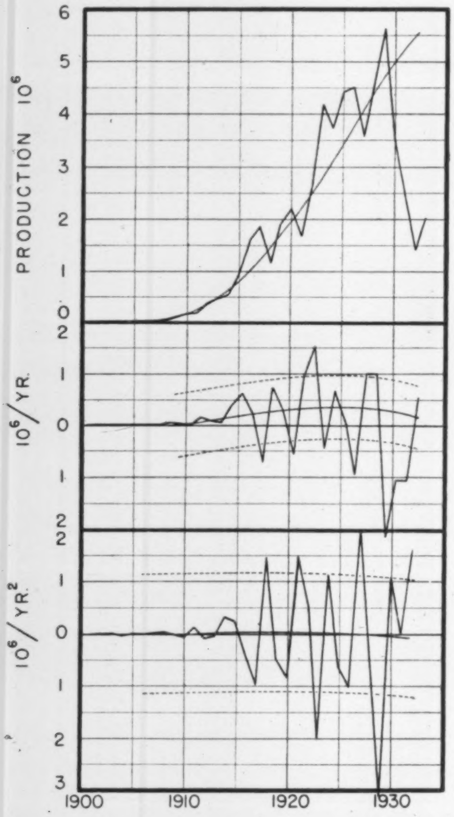


FIG. 6 AUTOMOBILE PRODUCTION, 1900–1933, WITH DERIVED VARIATIONS AND SECULAR TREND LINES AND BANDS OF OPERATION CONTROL

This means that if a new production figure falls within this predetermined band of operation p, conditions are what past experience has led us to interpret as usual and satisfactory. On the other hand, if the new production figure falls outside this band, either above or below, it can be concluded that some impacting force is affecting the business, either internally or externally, and warrants investigation.

ESTIMATION OF PROBABILITY[12]

It may now be asked, What is the probability of production at the last epoch for the succeeding epoch? As an aid in answering this question a special form of the probability table[13] is presented in Table 4. As equal amounts of a normal distribution lie on each side of the mean, only one-half of the entire table, which is expressed in terms of a unit area on a percentage basis, need be written. Column A, Table 4, shows that 50 per cent of the distribution of the data has been traversed from minus infinity to the mean or mid-point of the whole range, i.e., zero, in terms of the standard deviation, in column B. For values of A less than the 50-percentile, B is negative. The constant in Equation [13] was derived from this table.

The application of Table 4 to the estimation of probability in connection with the problem illustrated in Fig. 6 is as follows: The production of automobiles in 1923 was 4,180,000 cars. The growth-rate variation associated with this year $\Delta^1{}_{1922.5}$ was 1,534,000 cars per year. Based upon this much information, what is the probable production in 1924? Reducing this growth rate to terms of the standard deviation requires the equation

$$d = y/\sigma \ldots\ldots\ldots\ldots\ldots\ldots [14]$$

Then $d = 1534/1130.16 = 1.358$ as the standard deviation and from column B of Table 4, by interpolation, in column A, 91.28 per cent is found. The probability of increased production is given by

$$P = 1 - P' \ldots\ldots\ldots\ldots\ldots [15]$$

where P' is obtained from column A opposite the computed d of Table 4; e.g., in 1924 $P = 1 - 0.9128 = 8.72$ per cent.[14] Another estimate can be secured from these data.

TABLE 4 PROBABILITY TABLE

A	B	A	B
50	0.0000000	75	0.6744898
51	0.0250689	76	0.7063026
52	0.0501536	77	0.7388468
53	0.0752699	78	0.7721932
54	0.1004337	79	0.8064212
55	0.1256613	80	0.8416212
56	0.1509692	81	0.8778963
57	0.1763742	82	0.9153651
58	0.2018935	83	0.9541652
59	0.2275450	84	0.9944579
60	0.2533471	85	1.0364334
61	0.2793190	86	1.0803193
62	0.3054808	87	1.1263911
63	0.3318533	88	1.1749868
64	0.3584588	89	1.2265281
65	0.3853205	90	1.2815516
66	0.4124631	91	1.3407550
67	0.4399132	92	1.4050716
68	0.4676988	93	1.4757910
69	0.4958503	94	1.5547736
70	0.5244005	95	1.6448536
71	0.5533847	96	1.7506861
72	0.5828415	97	1.8807936
73	0.6128130	98	2.0537489
74	0.6433454	99	2.3263479
	99.37903	2.5	

The acceleration function associated with 1923, $\Delta^2{}_{1922}$ in Table 3, is 570,000 cars per year per year. From Equation [14] $d = 570/1677.17 = 0.340$, and from Table 4 the percentage is 63.31. Equation [15] gives $P = 1 - 0.6331 = 36.69$ per cent as a likely value. But further inspection of the data shows that the preceding acceleration was outside the control band which indicates, together with the receding growth-rate statistic, that production should not increase in 1924. Reference to Fig. 6 shows that it did not increase. This analysis has been made without regard to economic and political conditions.

MATURITY ANALYSIS

There remains the problem of the graphical determination of the probable quantity of production of the secular trend in time. Although the mathematical determination of this information by means of a logistic or other equations is possible, it seems that graphical results are superior in practically every instance. But the graphical analysis has a mathematical background; i.e., it is based on the theory of probability. The use of probability paper for graphical analysis was mentioned in the previous paper.[14] Probability paper can be drawn from the data in Table 4. Let the abscissas of the paper be linear for time and the ordinates be divided into plus or minus 2.5 units with the origin at the center. On this 2.5-unit linear scale plot column *B* of Table 4. To each corresponding value of *B* denote the correct value given in *A* and label in percentages.[15]

---

[12] This analysis is based upon the fundamentals of the theory of random sampling and probability.

[13] The equation on which this table was based is Equation [1] of the previous paper. See MECHANICAL ENGINEERING, June, 1934, p. 334.

[14] When using P directly read the result as "decreasing," instead of increasing. Equation [15] effects the change of the limits of the probability integral from $(-\infty$ to $x)$ to $(x$ to $+\infty)$. Therefore, it is seen that a probability of 50 per cent is recorded when the observation falls on the mean, indicating that the likelihood of an increase is just as good as a decrease (1 to 1).

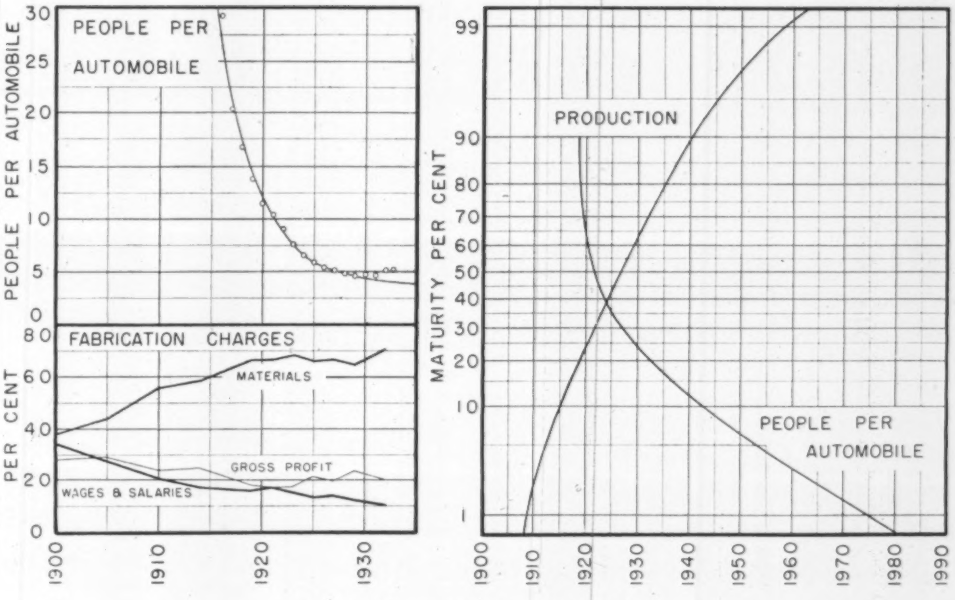


FIG. 8 AUTOMOBILE INDUSTRY

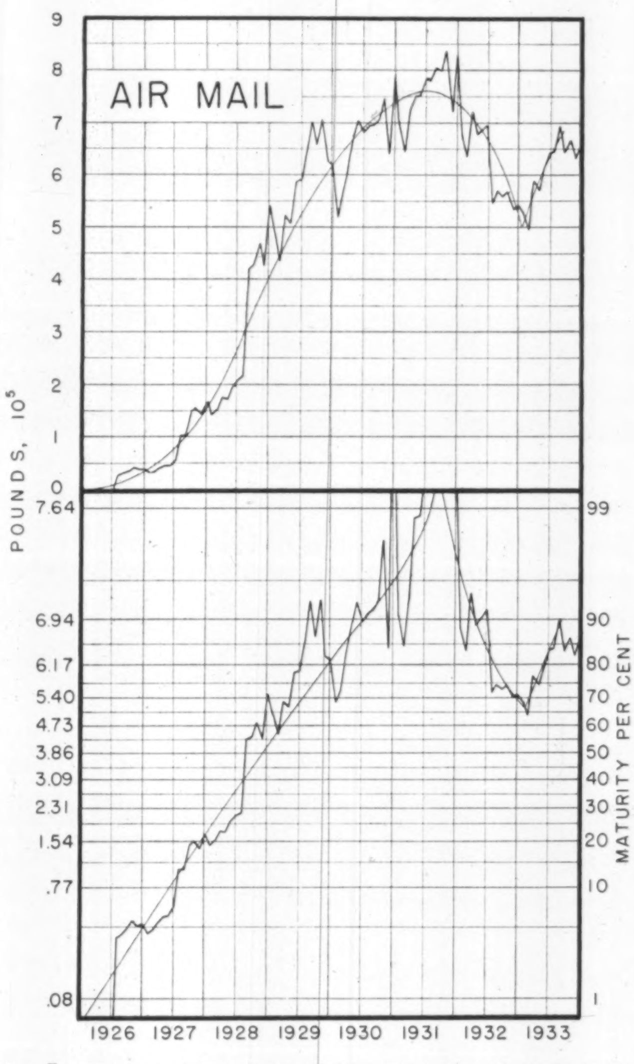


FIG. 7 GRAPHIC ANALYSIS OF GROWTH ON NATURAL AND PROBABILITY PAPER

The application of probability paper to the growth of the air-mail industry is illustrated in Fig. 7. Here the natural plot of the air-mail data is shown. The secular trend line has been obtained in the manner already outlined. This line is then replotted on the probability paper in such a manner that it will give the best "straight" line; i.e., by sliding it up or down on the probability paper. After the secular trend line has been located the actual fluctuations about the line can be plotted. This is most easily done by taking some point on the natural paper where the trend line and observation coincide. To this corresponding time the trend line on the probability paper indicates a known maturity percentage. From the ratio of these data any desired value can be calculated; e.g., the data and trend line coincide on natural paper at December, 1927, with a poundage of 166,000, while the equivalent maturity percentage is 21.5. The equation

$$\frac{166{,}000}{0.215} \equiv \frac{f'}{g'} = \frac{f}{g} \ldots\ldots\ldots\ldots\ldots \quad [16]$$

gives the physical volume of mail carried when f is in pounds and g is the desired maturity in per cent. From this equation the saturation is found to be 773,000 lb, while the chart gives the probable date as the fourth quarter of 1931 when the estimate is based on data through 1927. After saturation—100 per cent maturity—this immediate method of analysis does not tell the amount or direction of the next move. Suffice it to say that, for long-term planning, this method of estimating probable future trends and the epoch of the estimated quantity, on either symmetrical or skewed paper, is much more accurate than all other methods that were investigated. This air-mail figure has been shown because it illustrates an unusual situation and because, notwithstanding irregularities, all estimates made for this industry using these methods have been successful.

(Continued on page 500)

---

[14] Loc. cit.

[15] Fig. 5 of the previous article is constructed on probability paper. The positive-skewed-growth paper shown in Fig. 6 of the same article was constructed from a table that has been omitted for lack of space.

The skewed probability integral can best be given by the incomplete *B*-function ratio $1 - I_{1-x}$ (12.57, 2.74).

FRANKLIN UTILITY GLIDER IN FLIGHT OVER CORRY FIELD, NAVAL AIR STATION, PENSACOLA, FLA.

SOARING PLANES

Some Practical Considerations in the Design of Engineless Airplanes

By RALPH S. BARNABY[1]

THIS paper was prepared with two purposes in view: (1) To acquaint aeronautical engineers and designers with the problems of soaring-plane design in the hope that more of the talent that goes into airplanes in this country may be directed toward this interesting phase of aviation, and (2) to stimulate discussion among glider designers.

Soaring is sustained flight without power. It is accomplished by gliding in rising air currents whose vertical velocity is equal to or greater than the sinking velocity of the glider. These rising currents are either thermal or the result of a wind blowing against an obstruction, such as a ridge, and flowing up and over it like an inverted water fall.

SELECTION OF AIRFOIL FOR SOARING PLANES

One of the first requirements of a soaring plane must be a sinking velocity sufficiently low to take advantage of these ascending currents. Again, in order to be able to fly in relatively high winds, to enable it to get from one favorable spot to the next, and to pass through down-current zones as rapidly as possible, a high flying speed is desirable. These two requirements combine to make the requirement of a flat gliding angle.

The selection of the airfoil for use on the glider is a matter of utmost importance.

A simple sketch will make this evident. (Fig. 1.) Assume two gliders of the same minimum sinking velocity, one having this sinking velocity at an overall L/D (ratio of horizontal to vertical distances) of 10 and the other at an L/D of 20. Both will maintain altitude with the same minimum ascending current velocity, but the one with the flat glide angle will have a normal speed of twice that of the other. Because of this it can go through zones of low ascending or descending currents with less loss of altitude because it will be exposed to them for a shorter time. It can fly in higher winds and make headway to windward. For cross-country soaring these features are essential.

The present straight-line distance record is 137 miles; the record in the United States is 122 miles.[2] Since good cross-country soaring conditions are generally of short duration, starting not much before noon and ending with darkness, high speed is an important factor.

THE GLIDING DIAGRAM

The best way of studying and comparing airfoils, wing combinations, or complete soaring planes from this point of view is by comparison of their gliding diagrams. This diagram is constructed by laying off from a common origin along each of a number of flight paths the velocity of glide for each path. The locus of these points is the gliding diagram.

Fig. 2 shows a gliding diagram. In this case it was constructed from the airfoil characteristics of Göttingen 549, a good soaring airfoil. The numbers along the curve are the angles of attack.

The line *OC* through the origin tangent to this curve is the flattest gliding path. The distance from the origin *O* to the point of tangency *C* represents the velocity of glide along this path. The vertical distance *OA* from the origin to a horizontal line tangent to the curve is representative of the minimum sinking speed, and the distance from the origin to this point, *OB*, is the corresponding air speed. The line *OS* from the origin to the nearest point of the curve represents the stalling speed.

What is desired in the gliding diagram of a soaring plane? First, the tangent to the curve and through the origin should have as flat a slope as possible. (This means a high L/D.) Next, this point of tangency should occur as far to the right as possible to give high speed. Finally, the curve should hug this tangent to the left of the point of tangency to as low a

---

[1] Lieut-Comdr., Construction Corps, U. S. Navy.

Presented at a meeting of the Metropolitan Section, New York, N. Y., November 23, 1933, of The American Society of Mechanical Engineers. Abridged.

[2] Since the presentation of this paper, Richard C. du Pont, on June 25, 1934, piloted a glider from Elmira, N. Y., to Somerset Hills, N. J., a distance of 155 miles.—Editor.

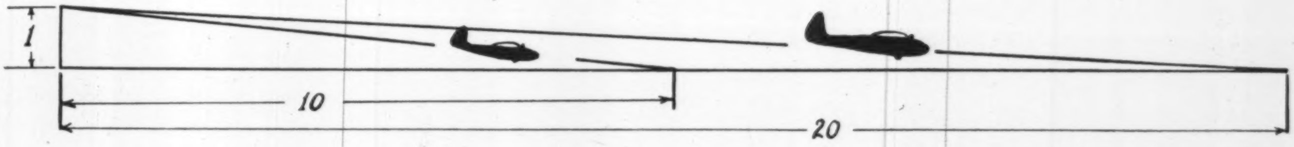


FIG. 1

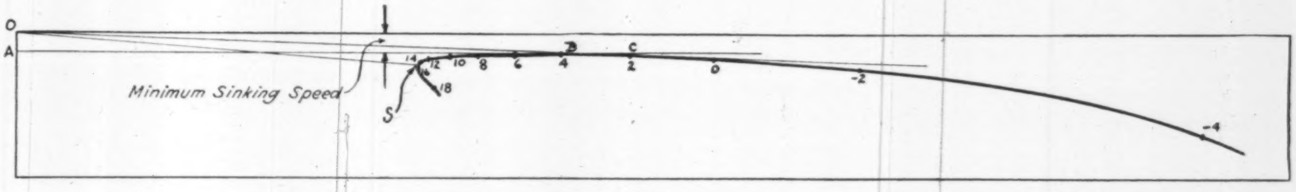


FIG. 2

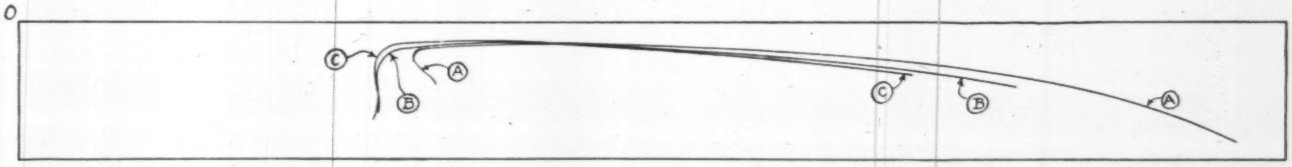


FIG. 3

speed as possible. This will give a low minimum sinking speed. A glider with such a curve can be flown over a large range of air speeds with a minimum sacrifice of altitude. For ease and comfort in flying, however, it will be well to have a comfortable margin between the air speed for minimum sinking speed and the stalling speed. It is rather trying on the nerves to be hanging on the edge of a stall for long periods of time.

Of course, in addition to a simple gliding diagram from simple airfoil data, there are many other factors which contribute to the final gliding diagram of the complete airplane. First, an airfoil, which has a fine diagram, may be too thin to carry spars of the depth required to carry the load. In such a case we must reduce the cantilever span by using struts, or thicken the wing, or both. The airfoil may be thickened by picking some other and thicker section or by increasing the ordinates of the original section. A method and data for estimating the characteristics of a section so "fattened" are given in N.A.C.A. Technical Notes Nos. 385, 391, and 404. If the increase is not too great it should be possible to approximate fairly accurately the characteristics of the revised airfoil. For correct results, gliding diagrams for the thicker airfoils must be compared with one made up for the wing-strut combination.

Aspect ratio is another variable in the wing problem. If it is increased the induced drag is decreased. But the structural problems become greater and the attendant drag increases. The choice must be made between a thicker airfoil, to take the cantilever wing loads, which will probably increase the profile drag, and bracing, which will add to the parasite drag. The many sizes, shapes, and bracings of soaring planes in existence attest to the fact that there has been no single simple solution of the problem to date.

Gliding diagrams can be compared to determine the best combination of aspect ratio and wing section. In Fig. 3 the gliding diagrams of three wing arrangements have been superimposed. Curve *A* is the diagram of a strut-braced wing, aspect ratio 15, based on the Göttingen 549 airfoil, the maximum thickness of which is 13.85 per cent of the chord. Curve *B* is for a cantilever wing, aspect ratio 15, based on the Göttingen 535 airfoil. This airfoil, because the thickness is 16.05 per cent of the chord, lends itself to cantilever construction. Curve *C* represents a strut-braced wing, aspect ratio 20, also based on the Göttingen 535 airfoil. From a comparison of these curves it appears that wing *A* has the flattest gliding angle and that it occurs at a considerably higher speed. Wing *C* has a slightly flatter gliding angle than *B*, and at a considerably higher speed. Wing *C* has the lowest sinking speed. It occurs, however, much nearer the stalling speed than in the cases of *A* and *B*. Wings *B* and *C* both have slower stalling speeds than wing *A*. As the speed increases the sinking speeds of both *B* and *C* increase at a faster rate than does that of *A*. In general it appears that wing *A* maintains an average of lower sinking speeds over a greater range of flying speeds than do either of the other curves. It would be the best wing, therefore, for all-around use.

Since increase in aspect ratio and properly tapering and shaping the wing tips in plan form reduce the induced drag, these refinements are necessary if high performance is to be obtained. Just how far to carry aspect ratio is debatable. While a number of the German soaring planes have gone higher, it seems as if there were little practical gain in going beyond an aspect ratio of 20. As the aspect ratio increases, so do the structural problems. The problem of taking care of torsion in a wing of high aspect ratio, especially if the glider is going to be subjected to the higher speeds involved in airplane towing, become serious. I believe that a successful all-around soaring plane need not have an aspect ratio of more than 15.

While it is well known that for the utmost performance all the aerodynamic refinements known should be used, I believe that more can be learned in the long run if some of them are sacrificed to produce a rugged plane capable of moderately high performance, or that will stand rough service and towing, that will cost less, and that can be flown more frequently than can the extreme types.

REQUIREMENTS FOR A "UTILITY" SOARING PLANE

Let us consider some practical requirements for what might be called a "superutility" or "utility" soaring plane.

It is frequently necessary to resort to airplane towing in order to reach altitudes where thermal and storm-front soaring become possible. This means that the soaring plane must be designed for gust-load conditions at airplane-towing speeds, with a liberal factor of safety. Under such conditions the torsional strength and rigidity of the wings become important factors because of the extremely low angle of attack necessitated by the excess flying speed.

WING CONSTRUCTION

Both strut-braced and full-cantilever wings are used in soaring planes. It appears that many practical, structural, and maintenance advantages may be gained from the use of strut bracing without sacrificing much in performance. Kronfeld's "Wien" is an outstanding example of what can be accomplished with strut-braced wings.

Probably the stiffest wing construction, for torsion especially, is that used for most of the German soaring planes. In this construction the spar, usually a box beam, is set well back in the deep section of the airfoil. The leading edge is of plywood and with the spar forms a tubular beam of elongated D-section. The monospar type of beam construction might be feasible, but when it is considered that it is necessary to cover the leading edge of the wing with some stiff material in order to maintain the correct airfoil section, it would appear that the advantage is with the D-spar, which puts this leading-edge fairing to work. It is obvious that with the large cantilever overhang and tapering plan form, the conventional two-spar, single-drag truss wing is quite unsuited because of its lack of adequate torsional strength and rigidity.

FUSELAGE, LANDING WHEELS, AND COCKPIT

Probably the most important consideration with respect to the fuselage is to provide a side profile with sufficient rise to the tail to permit the attainment of high angles of attack on the ground, both for take-off and landing. The crash of a two-seater soaring plane at Elmira last summer was chiefly due to the small permissible ground angle which prevented the plane from getting into the air. In automobile-towed launchings, the ability to use a high-angle take-off cuts down the ground run appreciably. Again, if we intend doing extensive cross-country flying, which after all is the supreme sport of soaring, it is practically necessary that we have a glider that can be set down in a small space at a low speed.

While plywood monocoque fuselages of oval cross-section undoubtedly have the lowest drag, I believe that first cost, ease of inspection and maintenance, and length of life dictate a fabric-covered, tube-frame fuselage, suitably faired by falsework and fairing strips. Considerable wear and tear can be avoided if the bottom of the fuselage is covered with a light duck rather than the usual covering fabric.

If the soaring plane is to be used only in shock-cord launchings from grass-covered take-off sites, a skid is sufficient and the weight, drag, and complication of the wheel installation can be dispensed with, but such a glider will have a very limited use and will hardly fall into the class of the practical utility soaring plane.

The use of landing wheels on gliders and soaring planes is a distinctly American innovation. It is undoubtedly a by-product of automobile and airplane towing. The relatively slow acceleration and resultant longer take-off run imparted by these towing means as compared with the shock-cord launching make the use of the skid impracticable. One day of average operation of a skid-equipped glider, auto-towed from the average airport, will wear out a wood skid. In addition, the convenience of the wheel in ground-handling puts the wheel landing gear in the class of practical necessities.

A single wheel is undoubtedly the most satisfactory from all points of view. It is light, has a low drag, and lends itself readily to a simple brake installation. Maneuvering on the ground with a single wheel is readily accomplished in a manner only possible with a two-wheel landing gear equipped with pedal-operated brakes, a complicated installation, at best.

For maximum maneuverability and control on the ground, the wheel should be located approximately under the center of gravity when the glider is in flying attitude. This, of course, requires the use of a skid, ahead of the wheel, which can be put in contact with the ground by raising the tail about 10 deg by the application of the brake or by pushing the stick forward. While it would be possible to set the wheel ahead of the center of gravity as is customary in airplane design, it would seriously impair taxiing and maneuvering on the ground, and would give no particular advantage. The angle between the normal-flight-path attitude and the tail-down attitude should be at least 15 deg.

Too much attention cannot be given to the arrangement of the cockpit and the installation of the necessary equipment. A comfortable well-arranged cockpit with properly installed instruments may be as important a factor in successful soaring as proper aerodynamic and structural design. For drag reduction and also in the interest of increased comfort a suitable cockpit enclosure should be provided. Its attachment should be such that it may be readily installed and removed. It must be held securely in place so that violent bumps will not dislodge it, but, on the other hand, one good shove should suffice to remove it in event it should ever become necessary to "bail out."

CONTROLS

The shape of the fuselage will have considerable effect on the type of controls to be used. The slender lines of the nose of the soaring plane practically require the use of rudder pedals rather than a bar, so that the feet may be kept close together. This same slenderness, further aft, interferes with lateral stick movement. In laying out the seat and controls the designer should bear in mind that flights of 6, 10, 20, perhaps more, hours will probably be made, and that since the pilot, because of the limited space, will be unable to shift his position much, the arrangement should be as easy and comfortable as possible.

In the design of the controls, every effort should be made to reduce friction and lost motion. In soaring, particularly, it is important that the pilot be able to feel the air forces on his controls. I know of few things more uncomfortable than flying a glider with controls aerodynamically sensitive and mechanically stiff. It is a practical impossibility to get the best performance out of a soaring plane in this condition.

Aside from the air controls, there should be conveniently located and so placed as not to be confused, the tow-line release, the brake control, and the tail release, if any.

A soaring plane to be universally useful must be capable of being towed by an airplane. This means that provision must be made for the installation of a parachute, which the Department of Commerce requires for such flights.

LAUNCHING MECHANISMS

After watching many shock-cord launchings, I am convinced that some positive means should be provided for releasing the glider for take-off. The usual method, in which men hang on to ropes attached to the tail, is hazardous for men and equipment. Some soaring planes are equipped with pilot-controlled trip hooks in the tail, similar to the towing hook used in the nose when the plane is launched by towing. This seems to me to be an unnecessary complication. My suggestion as the simplest and most foolproof method is to use what might be called a mechanical fuse, i.e., a tail attachment which includes a readily replaceable calibrated "weak-link" member, designed to break at the desired load. For instance, one simple device would be a shackle or clevis on the end of the hold-back line which would be held to a lug in the tail of the glider by means of a shear pin. Using copper, brass, and iron nails, and various tempers of copper, aluminum, and iron wire of standard diameters, suitable shear pins could be found that would take care of any desired release tension. Probably the best and certainly the most mobile anchor for the hold-back is the wheel or bumper of an automobile parked at right angles to the take-off direction.

EASE OF ASSEMBLY

Next in importance to strength and aerodynamic qualities comes mobility. In order to get the most use out of a soaring plane it is necessary that it be on the starting site ready to take off at the proper time. If a flight terminates somewhere away from the starting point, it must be possible to get it back ready to start again in the shortest possible time.

In designing the assembly features of a soaring plane, it should be borne in mind at all times that it may be necessary to assemble and dismantle it many times in a day. Alignment should be automatic. Bolts and pins should be neat, but the fit should not be too tight. The nuts on bolts should be free-running so that they may be readily run on by hand and tightened, where necessary, with a minimum amount of wrench use. Spring-wire safety pins are almost universally used for cotters for nuts and clevis pins. Push-pull rod controls are advisable from the assembly point of view. They halve the number of connections to be made and broken, and require no adjustment. It should be possible for three men to remove the plane from the trailer and set it up ready to fly in 15 minutes.

A two-piece wing is preferable to a three-piece wing. It is both lighter and more readily assembled. In some of the soaring planes of extremely large span the three-piece construction has been necessary because of handling and trailer difficulties. In the utility soarer the span will not be great enough to present these difficulties.

INSTRUMENTS REQUIRED

Of the instruments required, probably the most important is the barograph, yet to date few gliders have provided a suitable place for installing one. A barograph must be carried on every important flight and in any contest flight. It is installed just before and removed just after each flight. Much valuable time will be wasted if an accessible barograph compartment is not provided.

A soaring plane should be provided with a rate-of-climb indicator, an altimeter (preferably of the sensitive type), and an air-speed indicator. If one of the new-type sensitive altimeters is used, i.e., one in which the "minute" hand makes one revolution per thousand feet and the "hour" hand one every ten thousand, it will be necessary to provide some sort of vibrator for it, such as an electric buzzer or a reed sticking out into the air stream, otherwise the friction of the gear train produces so much lag as to render the instrument useless. (In an airplane the engine provides the necessary vibration.) If so equipped, however, the sensitive altimeter becomes a most important instrument, rating close behind the rate-of-climb indicator. If extended flights and cloud flights are to be made, a compass and a turn-and-bank indicator are necessary. One of the most important instruments is a watch, but the author is assuming that it will be carried on the pilot's wrist.

If long soaring flights are to be made it may be necessary to continue after nightfall, in which case running lights are necessary. Provision for the necessary lights in accordance with the Department of Commerce regulations should be made.

TRAILER DESIGN

After attending four national soaring contests and taking part in several independent soaring expeditions, I have developed some fairly strong ideas on trailer design. For instance, after having seen wing struts ruined by being run over by an automobile while laid out on the ground preparatory to assembly, I believe that the trailer should be designed so that parts may be removed from it for assembly in the order required and replaced on the trailer in the order they are dismantled. A trailer which requires that the wings be removed and laid on the ground in order to get out the fuselage is a distinct hazard.

Some of the roads leading to soaring sites are fairly steep. The lighter the trailer, the sooner the site will be reached and the longer the tow car will last. However, in striving for lightness there are certain features which should not be impaired or jettisoned. First of all, the trailer must be rugged enough to withstand distortion which might put dangerous stresses on the glider parts. It should protect the glider from the elements. It should be provided with adequate and convenient stowage space for tools, parts, and repair material. A small shelf with a vise is very handy. A substantial towing attachment is essential. The trailer wheels should be so located that there will be a moderate down-load on the towing attachment when the trailer is loaded. Wiring for a trailer tail light should be provided.

Wide World

RICHARD C. DU PONT AT THE END OF HIS 155-MILE FLIGHT IN A MOTORLESS PLANE, JUNE 25, 1934

STEAM *and* POWER SUPPLY

Discussion of a Paper by Vern E. Alden Read at the 1933 A.S.M.E. Annual Meeting

IN THE November, 1933, issue of MECHANICAL ENGINEERING, Vern E. Alden, power engineer, Stone & Webster Engineering Corporation, Boston, Mass., contributed a paper, read at the 1933 A.S.M.E. Annual Meeting in December, entitled "Steam and Power Supply." In it Mr. Alden discussed some general factors to be considered in planning steam and power projects for industrial plants. Mr. Alden considered such important problems as the correct estimation of the load and life of the plant; the economics of replacement of old equipment; the possibility of generating electric power as a by-product; considerations involved in the choice of the initial steam pressure; the variable relationship of steam and power loads; the different solutions that are likely to be found for large and for small plants; the vexing questions of reserve capacity, its extent, and what it shall consist of; fuel; the use of a single power plant to serve several industrial plants; and the desirable fundamentals to be embodied in contract relations. The discussion which was stimulated by the reading of the paper follows:

KERR ATKINSON DISCUSSES THE ECONOMICS OF A CONSOLIDATED STEAM AND POWER SERVICE

Kerr Atkinson[1] wrote: Mr. Alden has correctly said that betterment of efficiency without change of cycle rarely warrants investment for new plant construction. This statement suggests the corollary that even a basic change of cycle is seldom attractive when the new capacity provided merely substitutes for existing capacity that is already adequate though less efficient.

From 2 to 3 mills per kilowatthour is usually all the fuel economy an industrial by-product plant will realize over a condensing plant. On, say, 6000 hours' use of the capacity per year, this will save only $12 to $18 per year on an investment of $100 to $150 per kilowatt for a high-pressure plant. Only the exceptional combination of large fuel and incidental operating savings with low first cost will interest the industrial who usually wants a 5-to-1 ratio of investment to annual operating saving or better. Similarly, a large utility adopting a by-product cycle can save only 1 to $1^1/_2$ mills in fuel by investments of $80 to $110. The annual savings of $7 to $10 are far from handsome.

And so, it appears more often than not, where adequate generating capacity is already available whose fixed charges cannot be eliminated simply by abandonment, that new investment for a by-product cycle is unwarranted. However, where no previous commitments in plant exist or where additional facilities are needed to meet new steam and power demands, then the choice of a by-product cycle is obviously interesting, part or all of any old equipment remaining useful as stand-by capacity and obviating investment for spares in the by-product plant.

In other words, where capacity has a value, it is economic to install new equipment and it is economic to select the most favorable cycle. The major economy, however, where rapid payout of investment is desired, is not in low heat rate, as one might first assume, but in ability to provide two services from the same equipment.

The special and significant case where an industry may show truly handsome returns from a by-product plant is in competition with purchased power. For when a power contract terminates, the demand charge—which is the counterpart of the capital charge on power-system capacity—terminates with it; and this saving appears as the major economy to offset capital charges on by-product investment. The operating savings remain largely velvet.

Thus the strictly electric utility finds itself in a vulnerable position, faced with possible loss of net operating revenue applicable to fixed charges and return on existing facilities approximating two-thirds of the gross from power sales to large steam users. The utility may regain a basically strong competitive position only by offering combined steam and electric service at a combined cost to the user at least as low as he could produce it himself. To do this in a large way the utility must not only employ a favorable cycle but it must also invoke those advantages that are the fundamental reasons for the existence of public service; namely, diversity in demands, permitting high load factors; permanence as compared with transience of single industries, warranting low rates for amortization; and large-scale production affording low unit costs. Although its generating economies are not to be ignored, the by-product cycle becomes primarily important to the utility as a vehicle for offering rates for service that will get the business. The class of customers that affords the utility an opportunity to supply two services from the same equipment makes possible an economy in capacity charges that entitles it to special consideration. Any survey of consolidated supply of industrial requirements must include a careful analysis of the special needs and opportunities of each prospective customer as a basis for determining the value of the service to him. On this we may build an equitable rate structure which will interest him and at the same time compensate the utility for the risks it lifts from the customer and assumes itself.

From investigation of the economies of consolidated steam and electric service to a group of several industries, we have found that, in competition with industrial projects for completely new isolated plants, threatened loss of electric revenue may be wholly compensated by economies from the combined service.

Before this ideal competitive situation can be established, which presumes no existing investment commitments by either party, we must jump two hurdles represented by existing industrial boiler plants and surplus utility generating capacity.

To develop the inherent advantages of public service the enterprise should comprise two or more customers of fair size. Since only new industries in a territory, or those contemplating major expansion, are free of commitments for fixed charges on existing boiler and power equipment, the opportunities for combining several such requirements of magnitude in one area are rare. The foundations of a stable development of importance may be laid only by assuming the risks incident to securing existing steam business. To enter this field, the utility must temporarily assume the fixed charges on existing customer boiler plants, preferably by leasing or buying their remaining life. This is a necessary development charge to be ultimately retired from future earnings. Also, if the utility, like many, has idle surplus capacity on its system today, the capital charges on additional condensing capacity released by a by-product development must temporarily continue as a charge against current revenue until system growth shall again call the capacity into service. This accumulation may also be considered as a development cost although, when the alternative to a by-product project is loss of the power business and release of the capacity in any event, it may perhaps better be classed as cost of holding the business. When new capacity eventually does acquire a value, however, then the by-product investment may be credited, in computing rate of return, with the full estimated cost of adding equivalent condensing generation to the system.

---

[1] Engineer, Jackson and Moreland, Boston, Mass. Mem. A.S.M.E.

In connection with the subject of capacity value, it should be remembered that a 10,000-kw by-product unit, if installed in such a manner as to make the capacity firm, is just as valuable per kilowatt as any larger unit even though system-growth predictions may overlook it in estimating whether the next 100,000-kw unit will be required in 1935 or 1936. In its relation to peak capacity, the small unit is just as significant as any 10,000 kw of customer load on which the utility scrupulously imposes a capacity charge. It has been pointed out that, through lack of correlation between process-steam demands and system electric peak, it may be impossible to develop the full capacity of the unit from the process steam when needed. If the station is properly designed in the first place to permit developing the full rated capacity when process demands are deficient by exhaust to atmosphere or to a condenser if the probable duration of emergency operation warrants it, the capacity will be firm. No emergency boiler capacity need be provided for this purpose as the turbine water rates, under these conditions, would always be less than when supplying steam to process. Utilities are inclined to ignore the peak-capacity value of small units, and others have referred to recent stations actually constructed for steam supply only with low-pressure equipment because of this attitude—a failure to grasp an obvious competitive advantage and an opportunity to establish a basis for rendering fundamentally economical service.

When compared with sacrifice of existing business, our investigation of utility steam-electric supply showed that a by-product development would earn a moderate return even during the period before absorption of idle system capacity could justify a capacity credit against the new investment. After allowing capacity credit and before time for normal replacements of industrial boiler plants it showed a good return. The ultimate return, as already stated, more than restored the existing earning power.

Literally hundreds of industrials, awake to by-product advantages, have recently studied their individual circumstances and laid plans for reducing costs by independent generation at the earliest favorable opportunity. The time for the utilities to salvage millions of dollars of annual net revenue is now, before industrials abandon hope of utility service on a fundamentally economic basis and act independently.

We trust that those who finance utility programs may appreciate that a foundation laid now will save profitable existing business that cannot be recovered for a decade or more, if lost; and further, that the establishment of combined steam and electric service in any area will attract new business to the region.

F. L. BRADLEY CITES EXPERIENCE OF THE FORSTMANN WOOLEN COMPANY

F. L. Bradley[2] said: The Forstmann Woolen Company recently completed a power-plant construction program started only after a careful analysis of the controlling factors along the lines covered in the paper. The complete analysis of all phases of the problem demonstrated the desirability of building a new power plant in each of the company's two plants. The results obtained in the short period of operation of the new installations amply justify their construction and indicate conclusively the necessity of a careful analysis of the broader phases of the problem prior to a consideration of the details involved.

The management considered the broad and fundamental reasons calling for replacement of existing equipment:

(1) The necessity for reliability made a new installation imperative to avoid risking a plant shut-down due to failure of obsolete equipment.

(2) The old steam- and power-generating equipment was nearing an age where the cost of operation and maintenance was such that a substantial saving could be effected by replacement with modern equipment. While the cost of steam and power is by no means a large proportion of the overall manufacturing cost, it is large enough to make definite savings decidedly worth while.

(3) It was necessary to choose between either the provision of elevated storage capacity for treated and heated water for process requirements within the manufacturing area or consolidation of all such equipment in the power-plant building under the responsible control of trained personnel.

(4) The rehabilitation of the old boiler house and engine-room buildings located within the manufacturing areas made them available for manufacturing and service requirements. The new power plants were erected outside the manufacturing area.

(5) Moderate revamping of the existing steam, water, and electrical distribution systems included the installation of departmental metering equipment for cost purposes and the change to the use of low-pressure extraction steam for manufacturing wherever the cost involved could be justified.

Manufacturing conditions also imposed specific demands as to operating conditions that had to be considered in the general analysis of the problem.

Because of seasonal and even weekly and daily variations in the manufacturing demands for steam and power in almost every possible proportion to each other and with a heavy heating load superimposed in the winter, it was necessary to provide sufficient flexibility to meet any manufacturing condition quickly. This condition prompted the choice of automatic extraction turbines with surface condensers for the main electrical units which are operated almost entirely at maximum extraction rates for any given electrical load.

At the one plant, the heaviest steam demand in the mill was for steam extracted at 30 lb, while the lesser 100-lb steam demand was met by transmission at full boiler pressure to reducing valves at a central distributing point. At the other plant, the mill demand for 100-lb steam was of the same order as the demand for 20-lb steam extracted from the main turbines. In this case a small back-pressure-governed unit arranged for exhausting into either the 100-lb or 20-lb systems, or to a condenser, was installed.

In both plants, the power-house auxiliaries are turbine driven as far as feasible and they exhaust directly into the extraction steam system so that any steam in excess of the water-heating requirements is sent to the process. Ordinarily the water-heating requirements just about use up the auxiliary exhaust steam, but further flexibility for certain low-steam-demand conditions can be obtained by running the motor-driven boiler feed pumps, which are the heaviest steam-using auxiliaries, instead of the turbine-driven boiler feed pumps.

---

[2] Forstmann Woolen Company, Passaic, N. J. Mem. A.S.M.E.

Careful planning against plant shut-downs was also a requirement imposed on the engineering department by the management. Continuity of operation while transferring the load from the old plants to the new was successfully effected during the peak of the manufacturing season.

The problem also involved a careful analysis of steam and power demands to permit the selection of proper steam conditions. The electrical demand at one plant is fairly light compared to the steam demand, which is mostly for 30-lb extraction steam. Therefore, with steam generation at 250 lb per sq in., enough by-product electrical power can be generated for ordinary conditions with a reasonable margin for increase in electrical demands without going to more expensive high-pressure system. Since reliability was of such importance, it was felt that any piping 400 lb or over should be made up with Sargol-type flanges, rather than the lower-cost construction possible with 250-lb steam systems.

The electrical demand and the 100-lb steam load at the other plant are high enough in proportion to warrant generation at 450 lb, the pressure finally selected. Steam generation at 600 lb was considered but would under most conditions leave a deficiency of low-pressure steam which would have to be made by passing live steam through reducing valves.

The steam temperatures selected were 500 F at the one plant and 600 F at the other plant. These temperatures were selected because they met the power- and process-steam requirements very adequately and also provided protection to the existing steam distribution systems which are made up with cast-iron flanges and represent an extensive investment only to be replaced over a period of years. During times when low-pressure steam is supplied by reducing valves instead of by extraction from a turbine, it is possible that a break might occur from the higher temperatures if a higher initial steam temperature was used, thereby resulting in a serious process shut-down.

T. A. BURDICK WEIGHS OPERATING COSTS AGAINST INVESTMENT COSTS

T. A. Burdick[3] wrote: Mr. Alden has very aptly brought out the fact that the cost of power and steam in industrial plants is controlled by economy of utilization as well as by efficiency of production. It is rather unusual to find small alternating-current motors loaded to as much as 50 per cent of their capacity. The resulting loss in efficiency may run from five to ten points. Even large motors are often underloaded sufficiently to lose several points in efficiency. Likewise in heating buildings heat from low-pressure steam is wasted with reckless abandon through open doors and windows and uninsulated roofs, and by absence of temperature-control devices.

Mr. Alden illustrates an interesting and useful application of high-pressure steam in the typical example wherein an 8000-kw mixed-pressure turbine and boiler unit operating at 450-lb replaced 150-lb boilers and two 5000-kw condensing turbines, with a resulting saving in cost of electricity. However, he approaches another important phase of power economics without giving it due recognition.

The engineering profession is still looking to efficiency as a major objective. Engineers continue to speak of the cost of fuel and how reductions can be made in it by adding this or that to the equipment of a plant. They have come to realize—and Mr. Alden is telling them again—that fixed capital charges usually constitute more than 50 per cent of the cost of power and energy production. They have also come to realize that a high degree of efficiency has brought no rewards to those who have been responsible for its accomplishment, while it has tended to shrink the earnings of those who produce the raw materials for power and energy production. Still they are looking for higher efficiency in the use of fuel and are overlooking the most fertile field for economic improvement.

For years nearly all papers and articles on power generation have been speaking feelingly of the "rising cost of fuel" and have intimated that in order to maintain equilibrium there would have to be a corresponding increase in efficiency. The available supplies of fuel are so tremendous and they have been augmented to such an extent in recent years by increased production of petroleum and natural gas, that we do not need to live in fear of unreasonably high fuel cost.

A review of the situation leads one inevitably to these conclusions: First, efficiency comes at too high a price; we can no longer afford to pay the cost of high thermal efficiency. Second, new construction should revert to first principles of simplicity in a sincere effort to reduce capital costs instead of trying to do something further with operating costs.

To be sure, if capital costs are reduced it will hurt capital-goods industries but that injury can be far more than offset by an increased requirement for fuel, which will continue indefinitely. In so far as the individual welfare of any particular company with respect to power cost is concerned, it is far more reasonable to suppose that worth-while results can be obtained by attacking the major item of expense, i.e., fixed capital charges, rather than by hammering away at what is now a diminishing minor item.

It is now evident that much saving in first cost of a plant can be effected by discarding most of the heat-saving devices and other refinements which have been coming more and more into use ever since the days when plants first became afflicted with economizers. Yet when a thorough job of weeding out has been accomplished the plant will still be able to make a respectable showing in fuel economy, particularly if full advantage is taken of improved materials now available and of effective methods of obtaining high rates of heat transfer in the boiler. In the matter of overall economy, which includes labor and maintenance, the showing will be even better.

In what may be called the commercially efficient new steam power plant for today the most important features to be salvaged from advanced power-plant engineering practise have to do with safety and reliability. With simplicity as the guiding principle in design this plant can be made to give service equal to the best, can be built at the lowest cost per unit of capacity of any type of power plant, and will generate the cheapest power. Beyond this the cost of energy delivered from this plant will not be too far out of line with that delivered from plants having the highest thermal efficiency.

Such being the case I would like to recommend to power-plant engineers that they forget about fuel economy for a while and devote their talents to the problem of restoring plant designs to a "normal cost" basis to meet present-day requirements. Obviously, the reform movement should start in the boiler room with a vigorous attack on those towering monstrosities now spoken of as steam generators; it should continue, however, until no part of the plant or its equipment has been overlooked in the effort to reduce bulk and weight and eliminate unnecessary complications. Full use should be made of the welding art for ducts, structural supports, and condenser shells as well as for pipe lines. Boiler and turbine should be drawn closer together.

---

[3] New York, N. Y. Mem. A.S.M.E.

Very good steam plants were built a few years past at a cost of around $125 per kilowatt of net generating capacity. Simplified plants can be built for half of that sum. It is going to help power users to be able to do so, and it is going to help industry and labor. Within another year I hope we shall begin to see something along this line in some of our technical papers.

A. J. GERMAN DISCUSSES THE DILEMMA FACED BY THE PLANT MANAGEMENT

A. J. German[4] said: The question, "Shall we buy or generate," has come up at every A.S.M.E. Annual Meeting for some time.

While some excellent papers have been presented on this subject, still a great number of industrial concerns now generating their own requirements could save considerably by shutting down their plants and buying their power, and also a great number now buying their power, undoubtedly, could more economically generate it themselves, and in some cases buy power during the summer months and generate it during the heating season. The average heating season, in all of the New England states, besides a number of others, is about six months of the year. The question that naturally arises is, how will the management of an industrial concern come to a decision as to what would be the most economical set-up for his plant?

It is safe to assume that the management of every industrial concern has been approached by the sales force of the local utility company, and again it is safe to assume that in practically every case he is informed that a considerable saving could be made by stopping the generation of his own electric power requirements and buying it. Should the sales representative have reason to believe that a saving is somewhat questionable in a particular case, it requires a very honest man, indeed, to recommend that his client continue generating his own requirements, for it is his job to sell. When the management requests a report from his engineer as to which is the more economical set-up, it is to be expected that the average engineer shall do everything possible to prove that to continue generating for individual requirements is the more economical, for here, too, more so than in the case of the sales representative, his bread and butter depends on the operation of the industrial power plant.

What, then, is the management to do? Frequently there is no one in the management sufficiently informed on power-plant problems to make a comparison on the two conflicting reports. If the sales representative is a better salesman than the engineer, the generators will cease operating, and if the reverse is the case, the plant will keep operating; and in both cases, the decisions may be wrong.

Again, what should the management do in such a case? The answer is, with such conflicting reports, not to make immediate decision, but keep them in abeyance and apply for assistance to a competent neutral party, namely, a consulting engineer with nothing to sell but service. Here, too, most likely, the management has been approached by the consulting engineer proposing that future requirements as to heat, industrial steam, and electric power be thoroughly checked up by his expert engineers, with the object of giving definite figures as to the average annual cost of present operation and what it could be reduced to if certain changes were made, including the question as to whether or not electric power should be bought or generated. It seems to me that when the management asks the consulting engineers' representative to estimate the cost of such service the figures cause alarm, and, there being some doubt about the value of the investment, the proposition is rejected, with, in most cases, a loss to both the management and the consulting engineer.

While only a complete report can make sure what steps to take, I am also of the opinion that a brief "preliminary report" made by the consulting engineer, at a low cost, would very quickly prove to the consulting engineer whether a complete detailed report, at a greater cost, would be justified. It is possible that were the consulting engineer to approach the management with such a proposition, a greater number would be willing to permit the consulting engineer to step into their plants.

FRANK T. LEILICH SUGGESTS FINDING USES FOR STEAM DURING THE SUMMER

Frank T. Leilich[5] wrote: As Mr. Alden points out, the combined efficiency of the heat recovery from a well-planned steam-electric plant is quite high. It would seem that with the increasing use of central-station steam, the utilities should give serious consideration to the installation of relatively inexpensive capacity additions in the form of moderate-sized non-condensing stations exhausting into their steam-distributing systems, with the generators feeding into the network. Such plants should make possible an attractive price for steam and electricity, and with the advent of steam refrigeration for air conditioning, enlarge the economic field for the steam-jet apparatus, which, in turn, would tend to fill up the summer valley in the steam-load curve.

As Mr. Alden pointed out, no general solution is applicable to all problems of the steam and power supply of industrial plants. The geographic location, nature of the product, and unavoidable seasonal demands make each case a special one.

The writer has in mind one industry that requires a relatively large amount of electric power and small amount of process steam; yet in the cold season it requires a large amount of steam for heating its numerous buildings. Electric power for refrigeration is an appreciable percentage of the total load; yet the greatest demand for this is in the warm weather. It would appear that the solution for this plant would be steam-turbine generation exhausting into the heating system with extraction points for the relatively small amount of process steam required. Condensing operation would make it necessary to resort to a cooling pond. However, as the plant requires a large amount of cool water for warm-weather operation of the processes and air conditioning, the possibilities of the steam-jet refrigeration apparatus to absorb the exhaust from the turbines during the hot season should be carefully analyzed. Another combination is that of a Diesel and turbine, the turbine to carry the base load during the cold weather and supply the exhaust for heating, and the Diesel to carry the base in the warm season. Based on preliminary estimates, all-Diesel generation with heat-recovery apparatus and low-pressure boilers also show a saving over purchased power.

---

[4] Chief Engineer, Scovill Manufacturing Company, Waterbury, Conn. Mem. A.S.M.E.

[5] Consulting Engineer, Baltimore, Md. Mem. A.S.M.E.

MECHANICAL ENGINEERING

Vol. 56 AUGUST, 1934 No. 8

GEORGE A. STETSON, *Editor*

Justice to Unemployed and to Industry

WISCONSIN'S Unemployment Reserves and Compensation Act which went into effect on July 1 recalls articles on unemployment reserves by J. W. Hook and Sumner H. Slichter that appeared in the October, 1931, and February, 1933, issues of MECHANICAL ENGINEERING, respectively. Both were seeking, as does the Wisconsin law, to find some manner in which income may be assured industrial workers temporarily unemployed. Mr. Hook predicted that this country was headed toward compulsory "unemployment insurance that will force on industry a disproportionate amount of the load." In the Wisconsin law we see the first legislative attack and more such laws are sure to follow.

Industry should not be too supine in admitting obligations to the unemployed beyond those shared by all members of the body politic, for to do so would be tantamount to an admission that depressions are its responsibility whereas they are not. It is one thing to tide faithful workers over slack times, but quite another to create the impression that they are guaranteed against major economic disaster. There is much to be learned in working out justice for employee and for industry in matters of unemployment obligations and reserves. Wisconsin should prove to be an instructive clinic.

In a recently delivered address before the Industrial Advisory Board, Ralph E. Flanders made a constructive plea for "an end to unemployment." Briefly his proposal included limited monetary relief from unemployment reserves, unlimited work on socially useful tasks at subsistence wages, and public construction under standard conditions concentrated in periods of greatest unemployment. As a needed instrument of social organization to bring these into correlated effectiveness, he suggested a national system of employment offices, to which every one must go who seeks to draw on the unemployment reserve or who seeks subsistence employment. In the light of present trends, Mr. Flanders' plan will bear thoughtful study.

Motorless Flight Commands Attention

GLIDING silently and gracefully out of the sky late one afternoon this summer a youthful aviator set his motorless plane safely upon the ground 155 miles from his starting point. He had not been towed, but dodging from cloud to cloud to take best advantage of upward currents of air, he had sailed like a soaring bird in a series of glides interrupted by occasional ascents.

Elsewhere in this issue Lieutenant-Commander Barnaby, holder of the first glider license issued in this country, writes of the technique of soaring and of the design and the requirements of the planes by which such feats as Richard C. du Pont performed are accomplished.

Soaring as sport and motorless flight as a commercial proposition seem far apart today. To be sure, towed planes have crossed the continent, and experimental flights with a series of towed planes which can be cut off to descend with pilot and freight when destinations are reached have been tried. A recent dispatch from Russia tells of such an experiment, and for such a vast country, ill equipped with railroads and highways, the airplane offers possibilities that cannot be left unexplored. Today's experiment is tomorrow's practise.

Already for training in the handling of airplanes the motorless plane has proved its value. Prohibited from developing military aircraft after the War, Germany turned her attention to the motorless glider or soaring plane and experimented with both the technique of flight and the ship. Interest in this country has been keen also, as recent flights at Elmira, N. Y., in which du Pont has been participating, will testify. Motorless flight has reached a stage that commands the interest of engineers.

Encourage the Young Man

ELSEWHERE in this issue, in a report of the Cornell meeting of the S.P.E.E., attention is directed to the innovation of this year's program represented by the numerous conferences that extended over two days and a half prior to the opening of the general sessions. A significant factor in the success of this innovation is the strong interest that was developed among the younger members of this society in its work and objectives. These young instructors and junior professors attended the conferences in large numbers. Their interest and enthusiasm were keen, and if the benefits they derived are in any proportion to the seriousness of the manner in which they listened to and participated in discussion, engineering teaching will be permanently enriched and the S.P.E.E. abundantly repaid for whatever small expense the conferences entailed.

Engineering societies can learn a valuable lesson from this experience of the S.P.E.E. They too have youthful members, eager to participate in society work but ignorant of how best to do so and reticent about pushing themselves forward in gatherings of their elders and employers. The pushing should come from the elders and employers as it did in the case of the S.P.E.E. It was the officers of the society who opened the way for these younger men to proceed and who placed upon their shoulders the responsibility of planning the programs, securing the speakers, and leading the discussion. It became a youth movement in the best sense of the term once the idea was launched.

And in many cases it was the employers who made it possible for the younger men to attend the conferences. While it cannot be said of all engineering organizations that they discourage participation of young men in the affairs of engineering societies, it is true of some of them, and too many place unnecessary difficulties in the way of the progressive youngster whose initiative urges him into active society work and attendance at meetings. Many more are indifferent or fail to encourage the young man.

The E.C.P.D. Makes Progress

THE program of the Engineers' Council for Professional Development received a forward impetus recently when the announcement was made that funds were in sight with which to commence the difficult work of accrediting engineering curricula and when the Council of the Society for the Promotion of Engineering Education voted to accept the E.C.P.D. as an accrediting agency.

The S.P.E.E., one of the sponsors of the E.C.P.D., did well to inquire carefully into what accrediting means, for the engineering schools have other functions to perform than to train men to pass examinations for licenses to practise and to become members of engineering societies, and they are justly jealous of their right to resist the attempts of outsiders to dictate the character and make-up of their curricula. But more is to be gained than to be apprehended in the proposed set-up. After all, it is better to have a single cooperative accrediting agency to which the engineering societies and teachers are parties than to have one in every state, for what engineers do not do for themselves is likely to be done by others with results less to their liking. And standards are more likely to be raised than curricula are to be standardized, for it will be difficult for a school which fails to be accredited to explain its deficiency when it attempts to raise funds for carrying on engineering education.

The cost of conducting the studies necessary to form the basis for accrediting a school are to be borne in part by the schools accredited, the fee being proportional to the number of curricula for which the schools seek the accrediting. There can be little to grumble at in the arrangement as the expense of answering questionnaires from innumerable accrediting agencies would naturally exceed the charges levied by the E.C.P.D., and the result will have a useful significance far in excess of that of the combination of all of the others. The engineering profession is to be congratulated on its foresight and initiative in setting up this useful agency.

In addition to progress made by the E.C.P.D. in accrediting, it will be noted from the report of the action of the A.S.M.E. Council at its recent meeting at Purdue, reported elsewhere in this issue, that that Society has accepted the Council's so-called "minimum definition" of the engineer—in other words the minimum qualifications that entitle a man to be so designated—and is preparing to make the necessary changes in its membership grades to bring them into conformity with the grades suggested by the E.C.P.D. Surely the achievements of the E.C.P.D. in the few months of its existence are impressive and augur well for the future of the engineering profession.

Engineering Terminology

MANY mechanical engineers have a feeling of keen appreciation of the homely but expressive terminology of their technical language. The carriage and the apron of a lathe, the bed of a machine, wristpin, rat-tail file, such simple and appropriate designations as jet and surface condenser, V-threads, knee, saddle, and column, realistically applied to machine elements, cone pulley, spur gear, cross-cut and rip saws, live and dead centers, spark plug, butterfly valve, D-slide valve, and a host of other terms come readily to mind and indicate their humble origin amid craftsmen who applied familiar words that fitted naturally. No hobgoblin of consistency bothered the minds of those who chose these names; no etymologist was consulted; no scheme of latinized surnames to honor a discoverer and confuse a student was attempted. Even scientifically minded Watt hit upon so apt a term as horsepower, the virility of which is attested by its persistence even when applied to boiler capacity. A non-technical person can visualize a horsepower and the term foot-pound has utility, but kilowatt and erg have significance only to those who are in the know.

However, we must not permit our sentimental regard for these honest terms to lead us astray into looseness or inaccuracy of expression when no good purpose is to be served. Boiler horsepower soon ceases to have a realistic significance when used in connection with modern steam generating units. Brass, cast iron, steel, become generic rather than specific terms. Popular misnomers like heat cycle, when vapor cycle is meant, serve to confuse students and readily lead to inaccuracies of speech, which suggest that the fundamentals involved are not clearly understood.

It seems that two principles are involved. One is that the advance of technology has so far outrun the terminology that the old terms become inadequate and need careful qualification or even substitute expressions to insure clarity and accuracy. From the point of view of young men studying engineering, much is to be gained by insisting on accurate terminology and an avoidance of words that have confusing connotations. On the other hand it is well to avoid pedantry and fussiness that insist on tiresome and unnecessary precision. For example: Once it is established in such a paper as that on the Boulder dam penstocks in this issue that the pipes have an inside diameter of 30 ft, it is sufficient to designate them as 30-ft penstocks, which avoids the awkwardness of such an expression as 30-ft inside-diameter penstocks.

After all, it is a good rule to follow in any kind of writing to use the most accurate and appropriate term and to avoid pedantic fussiness. We shall find, as engineering grows, that we shall need new and more accurate terminology. Some may prefer constant entropy to isentropic, but let us not be content with an unqualified adiabatic (or substitute your own bete noire). And without losing the richness of our language, let us not be afraid to make use of new and correct terms.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

NEW TESTS ON STEAM LOCOMOTIVES

FOR about ten years the development of locomotive engineering in Germany has been carried out along two lines—standard locomotives and experimental locomotives.

As regards the former, the increase in the railroad system and the expectation that axle loads of 20 tons will be employed on many of the main lines has led to a number of new designs, first of all incorporated in high-speed passenger and heavy freight locomotives. These new designs were made with a view to producing a locomotive unit of good operating characteristics rather than one of unusual heat economy. The other view was to concentrate on heat economy in the rather narrow meaning of this term. This led to the development of several types of experimental locomotives in which increases in temperature and pressure were employed to bring about an improvement in thermal efficiency. This included turbine and high-pressure, as well as Diesel, locomotives. On the other hand, the pulverized-coal locomotive retained the conventional boiler, although it was equipped with special burners and special tender. In the hope of improving the performance from the point of view of costs another line of development has been undertaken aiming at burning low-grade fuels, such as finely ground dried lignite or pulverized semi-coke.

The German Railway Administration carried out these tests on a large scale, so as not to lose any time in the development work. At the International Railway Congress, Madrid, 1930, the matter of increasing the thermal economy of locomotives was given great prominence and the German report presented to that conference gave a description of most extensive experimental work along this line.

THERMAL ECONOMY ONE OF MANY FACTORS

Since the Madrid conference, however, an important shift in the point of view has taken place. As in the case of stationary engines, attention to thermal economy has ceded in importance to the consideration of total economy. F. Fuchs, in the German report prepared for the Second World Power Conference in Berlin, 1930, presented some statistical data on locomotive costs on German State Railways and brought out a most remarkable fact, namely, that the cost of coal amounts to only 23 per cent of the total cost of locomotive operation. In addition to the comparatively small amounts covering the cost of feedwater and lubricants, the following items represent the major part of the costs; fixed capital charges, maintenance charges, repairs, and wages. Since then the share of the cost of coal has come down to about 21 per cent, which means that the heat-economy factors affect only from one-quarter to one-fifth of the total costs.

In a second report to the same conference the present writer, Prof. H. Nordmann, pointed out that advantages in the way of heat economy affect favorably the total economy of locomotive operation only when they can be attained without an increase in the other cost items, which means if they are not negatived by an increase in first cost and cost of maintenance of the locomotive resulting from additional complications of design. This is supported by the views expressed by Najork and Wichtendahl who said that in a high-pressure locomotive a purely thermal saving is supposed to contribute enough to compensate for the increased first cost and cost of maintenance, but that this has not yet been accomplished in the experimental units.

In this connection consideration is given to the outage trend of new types of machines. Here the tendency to outage that results from the necessary cooling and reheating of the boiler, which can be avoided in standard locomotives, not only brings about a falling off in heat economy but makes it necessary to provide a spare locomotive. Operating troubles are particularly undesirable at the present time in view of the keen competition offered by other means of transportation. Because of this the attractiveness of radically new types of locomotives has decreased materially, and while further development will not be discontinued completely, it has little chance of progress in the present state of the art. Pulverized-coal locomotives have been the only ones which have given a uniformly satisfactory performance; it is not for nothing, however, that they operate with conventional boilers and engines.

In the light of these considerations the value of standard locomotives has increased considerably and impetus has been given to the effort to develop well-known, reliable, fundamental types of locomotives while retaining the main features of their construction. What is saved in the way of thermal improvements in such locomotives contributes to the total improvement of efficiency, because, when minor improvements are made without basic changes in the locomotive as such, there is no material increase in either the first cost or in the maintenance cost thereof. Such research work as is described here deals then with such purely operating problems as the adaptation of the unit for higher speeds and a closer knowledge of suitable selection between two-cylinder and multi-cylinder engines. Because well-known elements are being dealt with, the results of the research can be immediately applied in practise, while in the case of unconventional locomotives, a research into an ideal behavior of a device at the Grunewald Test Plant has to be followed by experiments with test locomotives and cannot be embodied into practical designs for a long time.

In the article under review the author gives information on some of the work performed at the Grunewald Test Plant with conventional locomotives.

The author first considers how the test figures on the most modern standard locomotives look and how far an increase in thermal economy can be carried without overstepping those limits of pressure and temperature which are today associated with standard construction, in particular, in so far as the boiler is affected.

In this connection it may be recalled that the Maffei turbine locomotive has a conventional boiler, although the firebox is of copper, and that it operates at a pressure of 22 atm; and the use of pressures of 25 atm in a boiler with a firebox made of special steels is clearly in sight. Enough information on heat economics of this prospective type is already available from the data collected from six German experimental locomotives representing various types of boiler construction, as well as from tests with the four-cylinder compound express passenger locomotive 04002 repeatedly mentioned in the technical press. However, it would be too early to give an all-inclusive idea of the behavior of a locomotive working with a steam pressure of 25 atm, as the matter of materials for such a unit is not yet settled.

WHAT TEST FIGURES SHOW

The next question is: What do these test figures show? The author answers this in part by a series of curves representing the behavior of the various types of German railway locomotives.

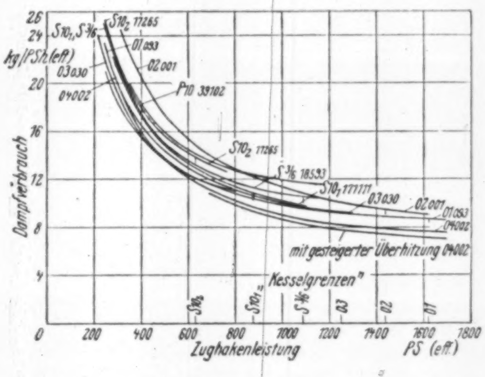


FIG. 1 (TOP) STEAM CONSUMPTION VERSUS EFFECTIVE OUTPUT, 57 KG PER SQ M PER HR "BOILER LIMIT" OUTPUT

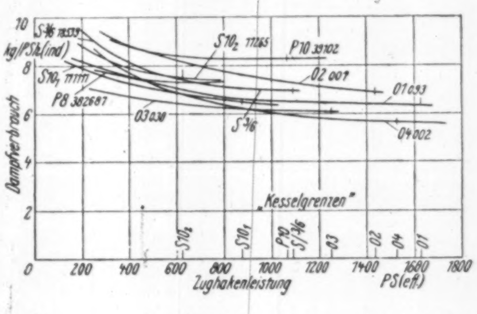


FIG. 2 (BOTTOM) STEAM CONSUMPTION VERSUS INDICATED OUTPUT

(In both figures, ordinates are steam consumption in kg; abscissas, output in effective horsepower at the drawbar; *mit gesteigerter Ueberhitzung* = with increased superheat; *Kesselgrenzen* = boiler limit output; PS = hp.)

Only the general conclusions are abstracted here and the curves are merely meant to give a general idea of what can and has been done without going into detail as to how it has been done. Fig. 1 represents the steam consumption for a locomotive operating at 100 km (62.1 miles) per hr plotted against the output at the drawbar. It is particularly necessary in such tests to state the speed at which the locomotive is to be operated, because the consumption to pull the locomotive and hence the efficiency as between the piston and the drawbar depend materially on the locomotive speed. The values given are of great importance, as they are derived directly from the basic quantities, namely, total steam consumption and output at the drawbar. Of this the former determines the maximum load on the boiler for an output at the drawbar available over a considerable period of time. The scattering of the bundle of curves, into the details of which the author does not go, represents the various thermal efficiencies of the locomotives. Single curves are affected by what the author calls "tolerances," independent of experimental errors, and representing such factors as whether the experimental trips were made in summer or winter, and to what extent the air resistance was affected by variable air densities. Moreover, a certain amount of lack of comparability of the figures results from the fact that the heat content of a kilogram of steam varies with the pressure and superheat. In themselves the best modern fast express locomotives consumed on the average about 9 kg (19.84 lb) per effective horsepower-hour at the drawbar at full load and at a speed of 100 km per hr. The consumption of 25-atm locomotives, series 04, has reached a value of 7.6 kg, and where a very high superheat has been employed, 7 kg per effective hp-hr. Consumption figures as against indicated output $d_i = \eta d_e$ (Fig. 2), for experimentally determined values of d_e lend themselves much better to comparisons up to the precision of the indicator. This is because here we have before us the actual working process of the steam cylinder and the great influence of mechanical total efficiency is nearly eliminated. Ultimately, this influence is that of speed and if it is not completely eliminated, it is because of the fact that throttling losses through the valve gear increase with velocity, while the losses through leakages at great velocities and smaller cut-offs decrease with the decrease of average steam pressures. At the same time the undesired heat exchange between the steam and the walls is also less because the duration of an individual stroke of the piston is smaller. These influences work in different directions and to some extent cancel each other, with the result that the value of d_i frequently falls off up to quite considerable speeds. The variability of these factors is not excessive, however, so that one can obtain experimental values which in their order of magnitude hold good for a wide variety of speeds.

Fig. 2 shows that 6.1 to 6.3 kg per ihp-hr is the best that German locomotives can do with steam at a pressure of 16 atm and a temperature of about 400 C (752 F). The 25-atm express locomotive showed about 5.6 kg per ihp-hr at a steam temperature of 410 C (770 F), and in locomotives with efficiencies raised by superheating, only 5.1 kg per ihp-hr. The heavy 1E type experimental locomotive for freight trains with a pressure of 25 atm and a four-cylinder compound engine has brought the steam consumption down to 5 kg per ihp-hr. It is freely admitted that these values suffer somewhat in precision because of variations of the heat content with the steam temperature. Therefore the steam-consumption figures as indicated by tests can be considered in connection with the heat value of each kilogram of steam taken at the temperature of superheated steam as determined by measurements and expressed in kilogram-calories per effective horsepower-hour, and recalculated by

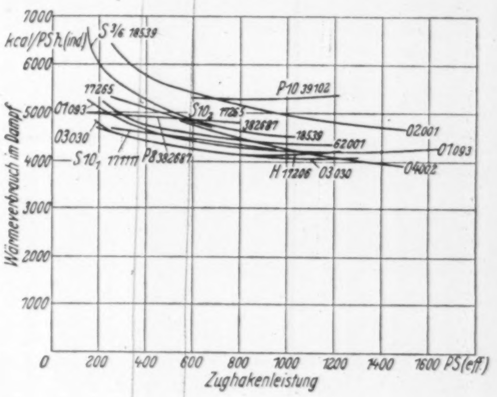


FIG. 3 HEAT CONSUMPTION IN TERMS OF STEAM PER INDICATED OUTPUT, KCAL PER IHP-HR AT THE DRAWBAR

means of comparative values obtained directly from the heat content of the coal. When this is done it will be found that the more modern locomotives, and also the good older S 10_1 locomotive, show the consumption between 6500 and 6000 kcal (1 kcal = 3.968 Btu) per effective horsepower-hour at 100 km per hr. It is only the 01 locomotive that goes a little below that while the 25-atm locomotive shows a consumption as low as 5500 kcal per effective horsepower-hour. This is a more favorable performance than that of the 60-atm high-pressure locomotive (double-pressure Schmidt-Henschel locomotive) as first built, and has been obtained by reconstructing the initially rather good S 10_2 locomotive.

It is claimed that the turbine locomotive does not show a very much better performance, from which the author concludes that the turbine type of locomotive does not have enough advantages as compared with the standard locomotive to make it very attractive, particularly in view of the fact that certain processes in the turbine locomotive are less desirable than those in the standard locomotive.

Fig. 3 shows the energy consumption in terms of steam for indicated output, the calculation starting from the preheater temperature, that is, after a deduction of the heat returned to the boiler by the exhaust steam. The indicated energy consumption has the advantage that it is only slightly affected by the train speed, and gives values of more general acceptability than the kilogram-calorie per effective horsepower-hour values so thoroughly tied up to the matter of speed. The best locomotives, among them the S 10_1 (but not the large 02 compound locomotive operated at the same speed), show performances below 5400 kcal per ihp-hr. The 01 locomotive (01093) shows up with 4200 kcal per ihp-hr, and an 03 locomotive, which has been tested along with the others, shows, possibly because of the excessively low value of η, 4050 kcal per ihp-hr, though another locomotive of the same series shows 4190 kcal per ihp-hr. The high-pressure locomotive H 17206 with its 4150 kcal per ihp-hr shows barely better performance than the 01 locomotive, but the new medium-pressure express locomotive with its 3900 kcal per ihp-hr lies lower than any of them. The still more favorable 25-atm freight locomotive, which, because of different speed, does not come under the same classification as the locomotives previously mentioned, operates on 3610 kcal per ihp-hr.

From an operating point of view a more important factor is the considerably lower steam consumption of the newer locomotives as compared with the older classes operating at steam pressures of 12 and 14 atm and at lower steam temperatures.

As regards the economically dominant matter of coal consumption in kilograms per effective horsepower-hour, which includes the boiler efficiency, the specific value for a speed of 100 km per hr is mostly a little over 1.3 kg of coal per hp-hr drawbar output. Only the 01 locomotive shows the lower figure of 1.27 kg. The 25-atm locomotive 04 runs on 1.05 kg per hp-hr. All of these values are expressed in terms of a standard coal with a lower heat value of 7000 kcal per kg (12,600 Btu per lb). These figures may be expressed in a different way in order to make it possible to compare them with figures for the consumption in stationary engines. In this case the consumption figures at the drawbar may be compared with the shaft horsepower of hoisting machines. To do this the figures have to be multiplied by $\eta = 0.7$ for 100 km per hr (the reason for this is explained elsewhere in the original article). This gives a different picture, namely, 0.9 to 0.72 kg per ihp-hr. The 25-atm freight locomotive, so excellent from the point of view of steam engineering, gives a figure as low as 0.67 kg per ihp-hr at 60 km (37.28 miles) per hr.

The author proceeds next to the consideration of consumption of coal as a function of speed, Fig. 4, for the case of a fully loaded boiler. He defines this as a "boiler limit," representing an output of 57 kg of steam per sq m per hr (11.7 lb of steam per sq ft per hr). In this case, in terms of output at the drawbar, in some instances the consumption is less than 1 kg per hp-hr. It is, for example, only 0.94 kg at 80 km (49.7 miles) per hr for the medium-pressure express locomotive (25 atm pressure) and only 0.84 kg for the 25-atm freight and passenger locomotive. One observes clearly the stronger rise of the curves for the compound locomotives, which go up when a speed of 90 km (55.9 miles) per hr is exceeded. However, this does not apply to the case of a less efficient, because of its oversize cylinders, S 10_2 locomotive. At lower speeds, however, the more recent compound locomotives 02 and S 3/6 with their better boiler efficiencies belong to the best of modern locomotives. The two 01 locomotives, belonging to different deliveries, do not have the same performance, partly because of the differences in boiler and cylinder, but also because of the difference in tolerances of measurement. The 25-atm locomotives show a superior performance not equaled by the other types.

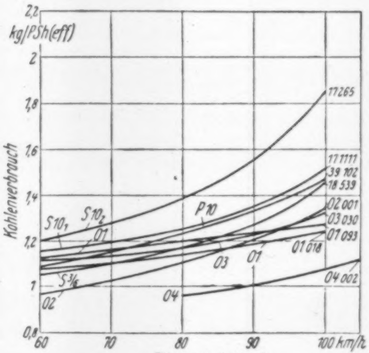


FIG. 4 COAL CONSUMPTION PER EFFECTIVE HORSEPOWER AT THE DRAWBAR AT THE BOILER LIMIT FOR VARIOUS SPEEDS OF TRAVEL

(In Fig. 3, ordinates, are heat consumption in steam; abscissas, drawbar output in effective horsepower; in Fig. 4 ordinates are coal consumptions in kg per effective hp-hr; abscissas, speeds in km per hr.)

There are many other questions affecting the further development of heat economy in conventional locomotives. One of these questions is whether it would not be possible to go still higher with the matter of superheat in the 25-atm locomotives, in order to avoid the region of wet steam with a great expansion in the compound locomotive during the exhaust stroke. Previous experiments have indicated the thermal impossibility of there being exhaust steam which has not yet lost all of its superheat. The further question is whether with simple expansion, which may be used to avoid compounding, similar attractive figures of consumption can be reached with lower pressures, perhaps 20 atm, but with a high superheat. This would have the advantage of employing lower average temperatures in the cylinder as compared with those now employed in the high-pressure cylinder of a compound machine, and the other advantage of lower stresses on the boiler materials, of particular interest because some of the difficulties in that field have not yet been completely overcome. This path of development looks particularly attractive because of reports on the coal consumption of some French locomotives operating with a boiler pressure of 20 atm.

The author proceeds next to the discussion of multicylinder and compound locomotives. (Prof. H. Nordmann, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 78, no. 24, June 16, 1934, pp. 729–736, 12 figs., *cA*)

Short Abstracts of the Month

AERONAUTICS

The Florine Helicopter

ON OCT. 25, 1933, this helicopter established a world record of duration of helicopter flight by remaining in the air for 9 min and 58 sec at a height of approximately 5 m (16.4 ft).

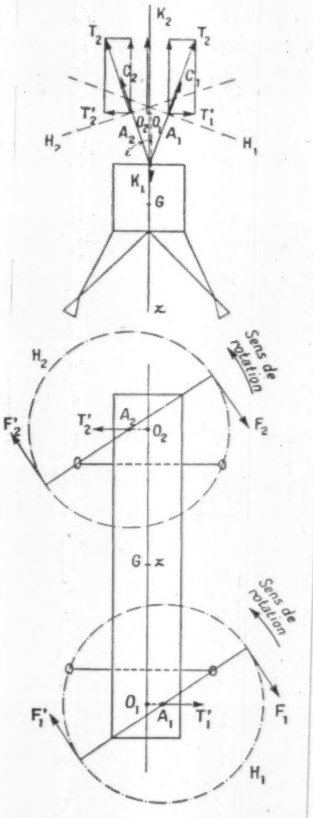


FIG. 1 DIAGRAM SHOWING THE BALANCING OF THE MOMENTS OF REACTION COUPLES WITH RESPECT TO THE CENTER OF GRAVITY BY THE INCLINATION OF THE AXES OF TRACTION PROPELLERS IN THE FLORINE HELICOPTER

(*Sens de rotation* = direction of rotation.)

The principle of the Florine helicopter may be generally explained as follows: The helicopter employs two propellers rotating in the same direction and placed at a sufficient distance apart at the extremities of a rigid structure. This arrangement has the advantage of utilizing the lift of each propeller at full efficiency as there is no aerodynamic interference between them. Moreover, it makes it possible to control, by the inclination of the axis, the equilibrium of the reaction couples and by this means insure the stability and maneuverability of the apparatus.

The complete analysis of the reaction couples with respect to the center of gravity of the apparatus and their balancing by the inclination of the axes of the propellers is given in Fig. 1.

The propellers H_1 and H_2, when inclined at the same angle to the vertical i, produce traction effects T_1 and T_2 which are equal if the propellers rotate with the same speed and if their reaction couples F_1, F'_1 and F_2, F'_2 are identical. If we project T_1 and T_2 on a horizontal plane passing through the hubs A_1 and A_2 we shall obtain two forces equal and parallel, but opposite to each other in direction. These forces produce a couple with respect to the axis G-z perpendicular to the plane and passing through the center of gravity. This couple has been represented in Fig. 1 by the vector K_1.

Similarly, if we project the reaction couples on to the same axis G-z and obtain their composite, the resultant vector K_2 will be directed in a sense opposite to K_1. For properly determined values of T_1 and T_2 and angle i representing the inclination of the axes of rotation, it will be obvious that the representative vectors K_1 and K_2 will be equal in magnitude and opposite in sign, and that the system of forces and couples will be in equilibrium.

There is another feature peculiar to the Florine apparatus. When a helicopter is displaced in translation along an essentially horizontal trajectory all the blades of its rotating members are not subjected to the same effects at every instant. Those which move against the relative wind are affected by a greater velocity than those which move into it. Because of this, if the blades are rigidly fixed in a hub, they are subject to periodic variations of stresses which produce fatigue of materials and assemblies and may result in breakage as a result of vibration or occurrence of resonance. To avoid this Florine has articulated the blades of his propellers around the hubs in such a manner that each blade undergoes a certain variation of incidence during each complete revolution. As the aerodynamic force is proportional to the square of the velocity and to the angle of inclination of the profile, the reduction of incidence with the increase of velocity makes it possible to obtain an aerodynamic resultant of very nearly constant magnitude acting on each element in the rotating structure. The availability of means to control the incidence of the blades also makes it possible to produce a moment of rolling in the desired sense. Tests on small-size models with propellers 0.60 m (23.6 in.) in diameter have been carried on since 1927.

Means for this work have been provided by the National Fund for Scientific Research (French). This permitted the building of a full-size unit operated with a 200-hp air-cooled Renard motor. The fuselage was made in welded-steel tubing giving a total weight of 950 kg (2093 lb). The mechanism for controlling the incidence of the blades is illustrated in Fig. 7 in the original article, but is not reproduced here because of lack of space. (Jean Lacaine in *La Nature*, no. 2925, Mar. 15, 1934, pp. 254–258, 7 figs., *dA*)

APPLIED MECHANICS

Cyclic Irregularity in Geared Transmissions

THE cyclic irregularity of an engine is the ratio of the difference between the maximum and minimum cyclic speeds to the mean speed. It refers to the condition in which the engine is driving a machine which absorbs constant resisting torque and which has a rotor of negligible inertia.

In calculating the cyclic irregularity of the engine it is assumed that the difference between the work done on the pistons and that absorbed by the driven machine during the same interval of time is equal to the change in kinetic energy of the flywheel. Hence it is possible to determine from a crank-effort diagram the maximum and minimum cyclic angular velocities if the mean velocity is known.

The cyclic variation of speed is of little importance in considering the behavior of gears which take the drive from the reciprocating engine. The criterion here is not variation of speed, but variation of torque, and the torque transmitted by the gears must never fluctuate so severely as to change sign and must never reach a peak value higher than the continuous capacity of the gears.

The author shows that the difference between the instantaneous torque and the mean torque at the engine coupling is $I_2/(I_1 + I_2)$ times the corresponding difference on the engine side of the flywheel, where I_1 is the moment of inertia of the engine flywheel and I_2 is the effective moment of inertia of the rotor of the driven machine.

Increase in the size of the flywheel reduces the torque fluctuation on the gears. It also reduces the cyclic irregularity figure for the engine. On the other hand, increase in the moment of inertia of the rotor of the driven machine reduces cyclic irregularity but increases torque fluctuation on the gears.

These remarks assume that the torsional stiffness of the shafts in the system is so high that the connection between engine and driven machine may be considered quite rigid. If, on the other hand, the natural frequency for torsional vibration is of the same order as the frequency of a harmonic component of the fluctuating torque exerted by the engine, torque fluctuation on the gears may become very severe. In the resonance condition, when the frequency of the applied torque coincides with the natural frequency, serious torsional vibration occurs and dangerously high stresses may be produced.

If the fluctuating torque has a component of the form $P \sin 2\pi pt$, where P and p are constants, and t represents time, the corresponding torque between flywheel and driven machine is given by $\frac{I_2}{I_1 + I_2}\left(\frac{1}{1-(p/n)^2}\right) P \sin 2\pi pt$, where n is the natural frequency of torsional vibration of the system.

It may be noted that this expression becomes of opposite sign to $P \sin 2\pi pt$ if p is greater than n, and that its numerical value becomes very small if $(p/n)^2$ is large. Consequently, the torque fluctuation produced at the gears by any periodic torque applied by the engine and represented by an expression of the form $P \sin 2\pi pt$ (a harmonic function of the time) may be reduced to any desired extent by making n a sufficiently small fraction of p.

It may be shown that any fluctuating torque of frequency p_1 may be resolved into harmonic components whose frequencies are integral multiples of p_1.

To make the natural frequency of the drive specially low, it is necessary to introduce torsional flexibility in the form of a spring coupling or a long, highly stressed shaft. The random application of such flexible connections is, however, worse than useless. The essential point is that the natural frequency of the modified drive must be higher than $1/\sqrt{2}$ times the frequency of the applied torque impulses; in other words, the special coupling or shaft must have a certain minimum degree of flexibility. If this condition is not observed, the torque fluctuation on the gears is likely to be greater than would apply in a torsionally rigid drive. This is illustrated by the case of a four-cylinder four-stroke internal-combustion engine driving a machine through gearing.

In conclusion, it is emphasized that a thorough investigation of the tooth-loading conditions in a geared-drive reciprocating machinery requires a crank-effort diagram and a knowledge of the moments of inertia of all the moving parts and the dimensions of all the shafts. Torsional flexibility below a certain amount actually increases torque fluctuation; beyond that amount its influence is effective in diminishing periodic peak torques and increasing periodic minimum torques. To avoid tooth separation, the amplitude of the fluctuating torque on the gears must be less than the mean torque which they transmit. (W. A. Tuplin in *The Engineer*, vol. 157, no. 4088, May 18, 1934, pp. 502–503, *p*)

ELECTRICAL ENGINEERING (See also Iron and Steel: Twin-Motor-Driven Blooming Mill)

Transmission of Energy by Direct Current at Extremely High Voltages

THE general scheme for the transmission of very large amounts of energy at great distances by direct current at very high voltages is based substantially on the following procedure. The electrical energy is initially produced in the form of three-phase alternating current in large high-speed generators which represent the most economic practise. The alternating current is raised to the desired voltage and converted into direct current by means of electric valves. The energy is transmitted in the form of direct current which at the receiving end is, again by means of electric valves, inverted into a three-phase alternating current, and then transformed to the desired voltage. As an example of what is desired to be done, the case of the transmission of approximately 1,200,000 kw from Norway to the north of France, a distance of about 1650 km (1003 miles), is selected. It is claimed that the cost of installation of such a system of transmission by direct current would be approximately only one-half of the cost of a similar installation for the transmission of the same amount of energy by three-phase alternating current, while the cost of transmission itself in the former case would be only about one-third of the cost in the latter case.

The author of the present report deals particularly with progress made since 1931, the date of his previous report to the same organization. He points out that since 1931 the size of the three-phase generators has materially increased. On the other hand, there has been practically no increase in the size of direct-current generators in these three years. He discusses next the matter of transformation of alternating-current energy into direct-current energy by means of electric valves and classifies the grid-controlled valves into three classes:

(*a*) Mercury-vapor valves with a mercury cathode (the ordinary mercury-vapor rectifier).

(*b*) Mercury-vapor valves with an incandescent cathode. This is the thyratron of the General Electric Co. where other gases than mercury vapor may be used.

(*c*) Incandescent-cathode valves with a high vacuum.

The majority of the larger electric companies of the world are busy perfecting special constructions of valves in these categories. It is too early yet to see which of these types of construction is best suited to meet the case of transmission of energy by extremely high-voltage direct current. In general it may be said that the valves classed under group (*a*) are particularly suitable for handling very large amounts of power up to medium voltages. Valves under group (*b*), which are characterized by a small drop in potential and moderate energy losses, seem to be particularly suitable for very high voltages and small amperage. It should be remembered, however, that it is too early to fix the limit of the amount of energy which these valves can handle.

Connecting high-voltage electric valves in series is a difficult matter at the present time in view of the ground capacity of the lines connecting the valves, their metal parts, refrigerating equipment, etc. It would appear, therefore, that the best procedure is to take the valves of group (*b*), of which a smaller number is needed and in which the earthing capacity is smaller than in valves of group (*a*).

Only certain features of this situation can be reported here. Among these it may be stated that it has been found that group (*a*) valves can be conveniently used to connect all the phases in one valve with a common vacuum, while with group (*b*) valves it is better to keep the phases separate and give each of them a vacuum of its own. It would appear therefore that the conversion of alternating current into high-voltage direct current can be carried out practically equally well with either type of valve. Electric valves of group (*c*) appear suitable for extremely high voltages and are most sensitive to grid control. The anode current can here be interrupted at any point of the voltage curve by the negative potential of the grid, something that cannot be done with those of either (*a*) or (*b*). These valves, however, have a poorer efficiency and it is difficult in their case to handle the heat caused by the very great fall of potential which takes place. They cannot, therefore, be used for the transmission of energy by means of high-voltage direct current. The largest vacuum electric valves equipped with control grids of group (*a*) built up to the beginning of 1933 have the following characteristics:

For quantities of energy up to about 6000 amp, about 700 volts and a total output of energy of about 4200 kw; for voltages of about 23,000, about 50 amp and 1150 kw. Vacuum valves of that type have been built for 16,000 amp and 800 volts but as far as the author is aware they have never been tested continuously at full charge.

The valves of group (*b*), which have notbeen in continuous service at their rated voltages, have been tested under factory conditions only. In addition to electric valves properly so-called, other types of rectifiers apart from rotative machinery have been or are being built: Among these the author mentions particularly the "electric-arc valve" built by Erwin Marx at the Polytechnic School, in Braunschweig, Germany, with which certain satisfactory results apparently have been obtained.

The author considers the transmission by very high-voltage direct current in either aerial or underground cables and says that where 220 kv were transmitted by alternating current, 450 kv can be transmitted by direct current, and he shows that a direct-current potential of 800 kv corresponds to a three-phase alternating-current potential of 400 kv. From the figures which he quotes it would appear that, as compared with transmission by three-phase alternating current, transmission by direct current with the same operating safety in the matter of conditions of insulation and with the same losses of energy due to resistance of the conductors will make it possible to handle twice as much energy by direct current. He makes particular mention of corona losses in this connection.

In analyzing the first cost of installation of a long line for the transmission of very large amounts of energy, the author states that the cost of installation of aerial cables for transmission by direct current is approximately one-half that for transmission by three-phase alternating current.

In the case of underground cables the first cost for direct current would be about 80 per cent of the similar cost for three-phase alternating current. The total loss of energy in transmission by direct current at 700 to 900 kv will not be in excess of 14.5 to 12 per cent, while the loss of energy in the transmission by three-phase alternating current at 400 kv is about 25 per cent. In fact, the author claims that the ability to employ underground cables instead of aerial lines is one of the most important, if not the most important, advantage in favor of transmission of energy at very high voltages by direct current, and is a factor which will play an important part in the future development of the transmission and distribution of energy.

The paper concludes with a brief passage dealing with the matter of inversion of current, that is, transformation of direct current at high voltages into a three-phase alternating current. The author considers as the most suitable apparatus for this purpose the Marx electric-arc valve to which reference has already been made. (E. Schjölberg Henriksen, Chief Engineer of the Norwegian Nitrogen Co., Oslo, Norway, Report No. 25 of the Conférence Internationale des Grands Réseaux Electriques, Session of 1933, vol. 1, 26 pp. and bibliography pp. 26–27, *dgA*. Compare in this connection a paper by M. M. Sitnikov of the Electro Physical Institute of Leningrad entitled, "On the Use of Thermionic Converters for the Transportation of Electrical Energy by Direct Current," pp. 1–9, 10 figs., *d*)

"Lead Pencil" Motors

In connection with very deep drilling a new type of pump known as the Reda pump has been introduced. It uses motors of 96 hp, 20 ft long, and less than 8 in. in diameter. The motor is provided with the Kingsbury thrust bearing on top and a gas separator. (*Electrical World*, vol. 103, no. 20, May 19, 1934, pp. 731–732, 3 figs., *d*)

ENGINEERING MATERIALS (See Metallurgy: Steels for Heat-Treated Gearing)

INTERNAL-COMBUSTION ENGINEERING

Comparative Tests With Gasoline and Butane on Air- and Water-Cooled Aircraft Engines

The experimental work, dealing, respectively, with an air-cooled and a water-cooled engine, was planned as part of a concerted effort toward an improvement in the fuel economy of engines in normal service. At the time when the work was started the fuel consumptions per brake horsepower-hour commonly met with were substantially higher than the best obtainable upon a single-cylinder test engine, and an element of uncertainty which, it was often suggested, must be held at least partly responsible. was inequality of distribution of the fuel between the cylinders on a multicylinder engine. It was suggested that this might be the cause of a difference of some 15 per cent between the highest thermal efficiency obtainable on a multicylinder engine and that reached under properly controlled conditions in a test engine.

It was decided to compare the fuel consumption per hour and the thermal efficiency of two typical engines, running on gasoline in the normal way, with the results when the same two engines were run using a gaseous fuel, which could be thoroughly mixed with the air at its entry to the induction manifold. Under these conditions, although a perfectly uniform dispersion of the fuel within the cylinders could not be taken as certain, inequalities of fuel distribution as ordinarily understood would, at any rate, be completely eliminated. A good many preliminary trials were made using coal gas as fuel, but the fundamental difference of chemical composition renders comparisons with gasoline on a thermal-efficiency basis uncertain, and butane (C_4H_{10}) was therefore decided upon as providing a gaseous fuel with molecules of the same general type as those of gasoline.

The results achieved in the experimental work, if regarded from the point of view from which it started, are largely negative in character; for they appear to prove that losses through inequality of fuel distribution cannot be greater than about 5 per cent and are therefore of secondary importance.

Apart from this answer to a particular question there are to be found in these reports many accurate data upon the efficiency-power relationship for aircraft engines, both supercharged and normally aspirated, and at altitudes up to 23,000 ft, more complete, perhaps, than any hitherto published. (P. H. Stokes and F. G. Code Holland, Department of Scientific Research, Air Ministry, Reports and Memoranda, No. 1570, July 14, 1933, 66 pp. and 28 diagrams, *e*)

External Air Compression

This process, the authors state, has been primarily developed for use on Diesel-engine locomotives. There are three or perhaps four main methods of producing a high range in efficiency by varying the air-compression pressure, namely, supercharging (Aufladverfahren), superinduction (Zuladverfahren), external compression (Fremdverdichtungsverfahren), and the Humboldt-Deutz process. In the supercharging process the cylinder is filled at the beginning of the compression pressure with slightly precompressed air so that a larger weight of air is made available and later on compressed by the machine itself. In the superinduction process a certain amount of highly compressed air is supplied from outside to the cylinders at the end of the compression stroke and thereby compensates for the lack of weight of air that it is desired to have present there. In the external-compression process there is no compression stroke at all in the engine proper, all the air being compressed externally to the engine and forced into the cylinder at the beginning of the expansion stroke. The Humboldt-Deutz process is a modification of the superinduction process, and has been described by A. Langen in *Zeitschrift des Vereines deutscher Ingenieure*, Vol. 77, 1933, p. 1287.

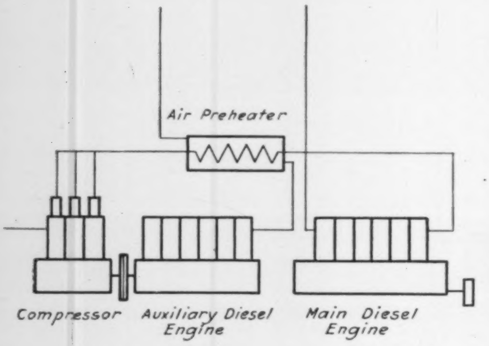

Air Preheater
Compressor
Auxiliary Diesel Engine
Main Diesel Engine

FIG. 2 (ABOVE) MACHINERY LAYOUT IN THE EXTERNAL-COMPRESSION DIESEL-ENGINE UNIT

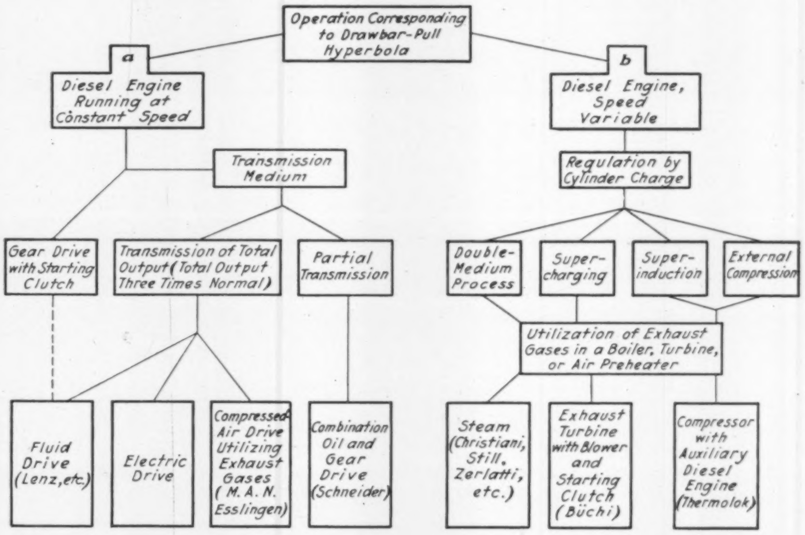

Operation Corresponding to Drawbar-Pull Hyperbola
a
b
Diesel Engine Running at Constant Speed
Diesel Engine, Speed Variable
Transmission Medium
Regulation by Cylinder Charge
Gear Drive with Starting Clutch
Transmission of Total Output (Total Output Three Times Normal)
Partial Transmission
Double-Medium Process
Super-charging
Super-induction
External Compression
Utilization of Exhaust Gases in a Boiler, Turbine, or Air Preheater
Fluid Drive (Lenz, etc.)
Electric Drive
Compressed-Air Drive Utilizing Exhaust Gases (M. A. N. Esslingen)
Combination Oil and Gear Drive (Schneider)
Steam (Christiani, Still, Zerlatti, etc.)
Exhaust Turbine with Blower and Starting Clutch (Büchi)
Compressor with Auxiliary Diesel Engine (Thermolok)

FIG. 3 (RIGHT) DIAGRAM OF VARIOUS TYPES OF DIESEL-LOCOMOTIVE DRIVE

Fig. 3 shows diagrammatically the machinery necessary for the external-compression process. This machinery consists of an auxiliary Diesel engine, compressor, air preheater, and main engine. The main engine works as a two-stroke-cycle motor in which the compression stroke has been replaced by an exhaust stroke. The air for the combustion is supplied from the compressor driven by the auxiliary engine. The amount of air supplied is therefore independent of the speed of the main engine, which makes it possible to connect the main engine rigidly with the drivers of the locomotive and to govern it like a reciprocating steam engine by the extent to which the cylinder is filled.

It is important to note that unlike the case of a Diesel-electric or Diesel-compressed-air drive the various parts do not have to be proportioned to take the full engine output. The auxiliary motor and compressor have to deliver a compression output theoretically equal to about 34 per cent of the total engine output, while the output of the main engine is reduced to the extent of the same 34 per cent, because the work expended by the auxiliary engine in compressing the air reappears here as useful work. As compared with a conventional Diesel engine, therefore, the main engine for the same output will be 34 per cent smaller. In order to obtain 100 per cent output, the following theoretical sizes of machinery have to be used: The auxiliary Diesel engine, 34 per cent; the air compressor, 34 per cent; the main engine 66 per cent; and the total, 134 per cent of the output. These are, of course, merely theoretical figures, which in practise are materially increased by various losses. Engine regulation by the degree of filling of the cylinders has the disadvantage that as the amount of charge increases the exhaust losses increase likewise. It becomes necessary, therefore, to find a way of keeping down the exhaust losses with an increased engine charge, and it is here that the process of external compression presents attractive economic possibilities by permitting an increase of the cylinder content of the main engine.

An increase of the cylinder dimensions does not affect the pressure and temperature stresses on an engine as long as the latter is not working with the same compression ratio. The increased dimensions, however, advantageously affect the efficiency, as the loss due to incomplete expansion is materially reduced.

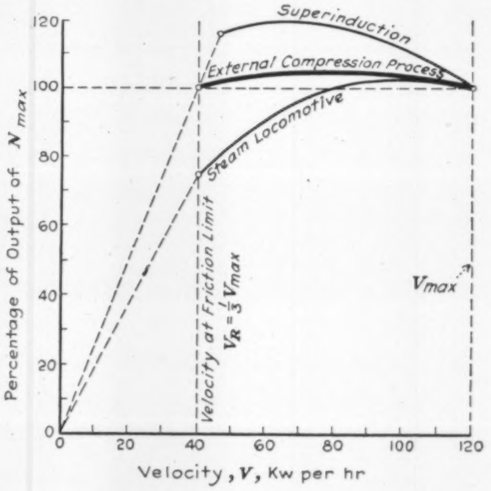


FIG. 4 CHARACTERISTIC CURVES FOR STEAM, SUPERINDUCTION, AND EXTERNAL-COMPRESSION-PROCESS LOCOMOTIVES

Comparison of the Various Processes. A thorough theoretical investigation led to the following comparison between the superinduction and the external-compression processes. The comparison was made on the basis of the output characteristics of a steam locomotive which must be equaled or bettered in order to make the application of the Diesel engine attractive. The ideal is a characteristic output curve running horizontally from the friction limit to the point of maximum velocity, as it is only under these conditions that the power-generating units are correctly employed. In all other cases a part of the plant is being uselessly hauled about. Fig. 4 shows the output-characteristic curves of a steam locomotive as compared to Diesel locomotives employing superinduction and the external-compression processes. In this figure the abscissas are velocities and the ordinates show percentages of output, taking maximum output N_{max} as 100, where this maximum output is used to get the maximum velocity V_{max}. The velocity at the frictional limit is one-third of the maximum velocity. The steam locomotive fails to give its full output at low velocities and the superinduction process at high velocities. The Deutz process not being a true superinduction process naturally gives a characteristic different from the curve for superinduction in Fig. 4. This curve is given in the original article and looks very much like the steam-locomotive curve in general appearance.

Weight. Minimum weight is one of the main requirements of a power plant for locomotives. This is discussed in detail in the original article. From this it would appear that the Diesel-compressed-air drive is the heaviest, the Diesel-electric coming next, followed by the superinduction process and with the external-compression process giving the lowest figure, slightly more than one-half of the weight of the Diesel-compressed-air process.

The original article gives a table showing the principal dimensions and characteristics of the Diesel-motor compressor set.

Efficiency. The high thermal efficiency is not the only reason for preferring the Diesel engine to the steam locomotive, but is a material factor. As long as the Diesel drive can maintain the same degree of reliability as the steam locomotive, preference will be given to the process showing the highest total efficiency. The original article shows efficiency curves on locomotives with superinduction and external-compression processes, the latter being very much higher than the former up to certain speeds. At top speeds the efficiency of the external-compression process falls off while that of the superinduction process continues to increase. Fig. 3 is of interest in that it shows proposed methods for operating locomotives by Diesel-engine power. (Doctors of Engrg. Siegfried Grantz and Paul Rieppel in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 78, no. 14, Apr. 7, 1934, pp. 436–438, 6 figs., *c*)

IRON AND STEEL

Twin-Motor-Driven Blooming Mill

DESCRIPTION of a drive installed in a blooming mill by a large mid-western steel company to roll beam blanks as the initial operation in producing wide-flange beams, and also of a 44-in. slabbing mill. Both of these mills require an unusual amount of power, which led to the adoption of a new type of drive. In this case individual 5000-hp reversing motors are directly connected to the top and bottom rolls without pinions.

With the scheme of control provided it was not contemplated that roll speeds should be matched as such, but rather that the loads on the driving motors be matched independently of roll speed. However, with metal between the rolls a coupling would be established, naturally tending to maintain the same roll peripheral speed. There was fear that for various reasons either the roll would slip or the piece would be elongated more on one side than on the other, and would curve either up and away from the mill tables, or down and on to them. In addition the slabbing-mill operating department felt that it would be desirable at times to operate with rolls of somewhat different diameters. The scheme as finally worked out makes possible not only the control of the tendency of the piece to curve but allows the use of rolls of different sizes as well.

Each 5000-hp motor is itself made up of a double-armature unit, with armatures connected in series. Each armature is wound for 350 volts and the two are parallel with the two armatures of the second 5000-hp motor across 700 volts supplied by three 3000-kw generators, themselves connected in parallel.

Each motor has a cumulative series field and a differential series field which are cross-connected and indirectly excited by series-excited generators. Any tendency of one motor to take more than its share of load strengthens its own field and weakens the field of the other motor, thus reestablishing load balance. It will also be noted that the motors are provided with separately excited shunt-field windings connected in series.

By moving the resistance tap one way or the other, the excitation of one motor may be increased and that of the other decreased, thus unbalancing the excitation sufficiently to permit balanced loads at unequal revolutions per minute of the two motors; these may be set to correspond closely to the difference in diameter of rolls used. With steel between the rolls a coupling is formed so that there is very little actual difference in the peripheral speeds of the rolls, although one motor may be made to exert more force than the other, thus probably establishing a slightly greater flow of metal on one side of the piece than on the other, and causing the piece to curve. While there is, of course, no occasion for doing so, it is possible sufficiently to unbalance this excitation that the entire load might be carried by one motor, or even that the other motor might be driven as a generator. (L. M. Gumm, Westinghouse Elec. & Mfg. Co., in *Electrical World*, vol. 103, no. 22, June 2, 1934, pp. 804–806, 5 figs., *d*)

MACHINE SHOP (See Metallurgy: Steels for Heat-Treated Gearing)

MANAGEMENT

Incentives in Repetitive Work

THE results of certain recent investigations on this subject for the Industrial Health Research Board (Great Britain) have been published in a report entitled, "Incentives in Repetitive Work—A Practical Experiment in a Factory." These investigations were carried out in a commercial factory where the only change made was the replacement of the usual supervisors by the individuals making the observations, and a period greater than one year was devoted to it.

The subjects of the tests were ten girls aged between 15 and 16 years, selected from a number of applicants on the basis of personal characteristics, as shown during an interview and in the performance of special tests. Different temperamental types were purposely chosen, as this factor was believed to have an important bearing on the question in hand. It was also considered desirable to find out how the same individual responded to different processes. The operations were five in number, and consisted of unwrapping, to correct the faulty work of machines, wrapping, packing, weighing, and a combination of weighing and wrapping. The ratios of the number of units dealt with in the same time were 40:20:12:6:1, in the order given. The output of each worker was noted every quarter of an hour.

First, the operatives were paid a fixed weekly wage, this condition holding for nine weeks; this was followed by a competitive bonus system for fifteen weeks. In this stage the girls were ranked each week according to output, and the slowest was given the same wages as before. The next best received an extra 6d, and so on through the group, so that the best got an extra 4s 6d over the slowest. This system was followed by a flat piece rate, which remained unchanged for twelve weeks. Within the time-rate period a relatively small rate of improvement, some 12 per cent, was noted, and there were indications that the continuation of this method of payment would be productive of no appreciable further increase in output. When the bonus system was introduced, there was an immediate rise of production by 46 per cent. Although the rise continued for a time, the output ultimately became fairly uniform, and a further change in the method of payment was thought desirable. The piece rate was then introduced, and the output increased 30 per cent, and, after a slight temporary reaction, this was maintained, with very little variation. It was evident that a time rate provided very little incentive to work, and the performance was much below capacity. Stimulation came with the introduction of the bonus system.

In a subsequent stage of the experiments, attempts were made to discover the effects of further changes in the system of payment. The three methods were then applied simultaneously to the different processes; that is, some were done on piecework, some on time, and the rest on the bonus system. The average output remained practically the same for the work done on the piece rate; an increase was shown in the case of reestablishment of the bonus system, possibly due to the diversion created tending to counteract the effects of the monotonous conditions of work; but the revival of the time rate resulted in an immediate and significant decrease in output. The restoration of the old indifferent attitude of output was most marked. It seemed that some form of payment by results was desirable, but a piece rate was considered impracticable because of the increased output, which would generally involve a periodic cutting of rates. The rate of improvement under the bonus system was always greater than that recorded under the time rate, and the superiority became more marked in each successive week. In the ninth week the difference was almost 35 per cent. Dealing with the groups of operatives in the factory instead of individuals, a sharp increase in output was similarly noted when the first bonus was introduced. The immediate increase was approximately 20 per cent, and the subsequent output continued to fluctuate around the level required for the bonus.

When the output on which bonus was earned was raised there was a further increase in production of about 18 per cent, which was more than maintained during the period of observation. Thus, the introduction of a bonus system dependent upon reaching a certain level of output acted as an additional incentive to ability, and in this respect the results agreed with those obtained in the main experiments. With experienced workers the introduction of a piece rate resulted in an average increase in output of 36 per cent. While the operatives worked in a careless and indifferent manner under the time rate, they devoted more attention to the machines under the piece rate, which resulted in fewer and shorter stoppages. The beneficial effect was therefore not confined solely to the output, but applied also to the life of the machines. Output seemed to become stabilized at a level proportionate to the monetary incentive. A change from the time rate to a bonus or piece rate broke down indifference, and resulted in a new level of output, usually from 20 to 40 per cent above that found under a time rate. In the survey it was found that the rate of working was closely related to that of their immediate neighbors. When each individual in turn was isolated from the remainder of the group, the average output of the isolated workers increased from 20 to 50 per cent. One point brought to light was the marked response of operatives to slight changes in conditions of work. In particular, they became unduly discouraged by minor difficulties. This seemed to be due to the monotony of the conditions, so that comparatively minor variations produced very important effects. (*Engineering*, vol. 137, no. 3567, May 25, 1934, p. 592, *e*)

MARINE ENGINEERING

The Isherwood Arcform Ship

THIS is the first time that complete information as to the shape of the Arcform ship has become available. In the past it has been accepted as absolutely necessary that the midship section of a cargo vessel be of the utmost fullness, this having been considered necessary to obtain the greatest displacement on a given breadth. Isherwood's study led him to the conclusion that the general tendency toward a box-shaped middle body was wrong. The flat bottom, vertical sides, and full bilge of the stereotyped design inordinately increase the wetted surface, which is an important factor in ship resistance, particularly in vessels of moderate speed. His investigation led him also to the belief that the box-shaped form gave rise to unduly high wave- and eddy-making resistances.

This led Isherwood to devise an "arc" form of transverse section to replace the old rectangular box section of equal area. Tank experiments were then carried out at Teddington and afterward in Holland and America, and on the strength of these it was decided to proceed with the construction of the first three of these ships.

In the *Arcwear* for which particularly detailed figures are available the coefficient of fineness has been reduced from 0.995 to 0.90, this being the measure of the increased fineness of middle body on which so much depends. The block coefficient has also been reduced from 0.777 to 0.702.

The full information about the ships was given by Sir Joseph Isherwood in a paper read on May 10, 1934, before the North-east Coast Institution.

The propelling machinery of the *Arcwear* is of the triple-expansion type, with cylinders 21.5 by 37 by 62 in. and 42 in. stroke, of 1750 designed indicated horsepower. Steam is supplied at 220 lb pressure with a temperature of 630 F from two main boilers and one auxiliary boiler. The machinery is equipped with double-beat poppet valves for the high-pressure cylinder and superheating, but is of conventional type without any special plant or appliances fitted to it.

The experience gained with the *Arcwear* on trial and in service is said to have justified the expectations formed as a result of previous tank experiments. On the 24-hr loaded trial at sea, the average speed was 11.15 knots and the mean indicated horsepower 1416, the coal consumption being 20 tons per day for all purposes. The Admiralty constant was 425, and the coal coefficient 30,100, with ordinary North country coal. Results for ordinary steamers vary largely, but the Admiralty and coal coefficients quoted might fairly be compared with the conventional figures of 270 and 19,000, respectively, giving a great advantage in favor of the Arcform ship. The first two voyages to South America and back have yielded equally good results, the loaded steamer burning an average of $16^3/_4$ tons a day with a mean speed of 10 knots.

The new form has produced a steady and comfortable sea boat, the captain reporting her rolling throughout these voyages to be easy and not excessive with a very high beam swell, and stressing "the very excellent way in which the ship goes into a head sea" as being "a great point in favor of Arcform." As these vessels are constructed on the Isherwood combined system, with longitudinally framed decks and bottoms, the captain would have no fear of the decks crumpling and collapsing in heavy weather, and would be able to take full advantage of the extra speed of the Arcform ship, because there would be no necessity for slowing down to the same extent, nor heaving to, as in an ordinary transversely framed ship.

In view of the particular fineness of the model at the lower part, an Arcform ship is considerably deeper in the water in the light condition than a comparative box-formed vessel, so that the ballast voyages, which the present unfortunate conditions of international trade render so common, can be made with greater speed and safety; the propellers in the Arcform ships having better immersion, the vessels are less likely to make leeway and become unmanageable, because of their increased draft in the ballast condition.

There is also a considerable increase in the longitudinal strength of the hull structure because of the greater breadth of the Arcform vessels at the deck, raising the neutral axis of the sectional material, and disposing it so as to form a more symmetrical equivalent girder than is usual in a ship fitted with a double bottom. The side framing also is of arched form throughout the greater part of the length, instead of straight-girder form, and is thus far stronger and stiffer. On account of the structural advantages, both of the Arcform and the Isherwood combination system, the whole design is markedly superior in strength and rigidity to the ordinary transversely framed ship, and this is accompanied by an appreciable reduction in hull weight. (*Engineering*, vol. 137, no. 3566, May 18, 1934, pp. 574–575, *dA*)

Velox Boiler for Marine Use

THE original Velox boiler was of the explosion type and the fuel and air mixture was actually exploded in a closed vessel. The present article describes a modified type in which the explosion principle has been replaced by one using constant pressure for the fuel and air supply. The outstanding features claimed for this new design are the maintenance of very high efficiency over a wide range of loads from units occupying less space than the orthodox design. There is no claim that the capital cost is less.

The method of steam generation is to circulate the water at high velocity through the evaporating tubes and then through a specially designed separator. The water and steam complete the circuit through evaporating tubes and separator at the rate of about ten times the full-load evaporation. The tubes are of small diameter and enclosed in fire tubes. The deposits from the water collect in the drum as a sludge at the bottom of the separator.

The most interesting feature of the Velox boiler is the arrangement on the combustion side. Combustion takes place in the combustion chamber under high pressure (about 35 lb per sq in.) and results in high velocity of the gases. The hot combustion gases pass through this steam generator and then through the superheater with only a small drop in pressure, when they enter the gas turbine at a temperature of about 900 F. Here there is a drop in pressure to about 16 lb per sq in., and the gases pass on to the economizer. It will be seen, therefore, that the gas turbine operates under suitable conditions as regards temperature, and the energy generated is converted into air pressure by means of a direct-coupled air compressor; this compressed air in turn passing to the combustion chamber of the steam generator.

The Velox boiler is, therefore, a new combination of existing units and reveals a new point of view on the problem of steam generation. The steam-generator unit operates under high rates of heat transfer, and in construction consists of a relatively small amount of material. In one example given a 50,000-lb boiler was brought up to full pressure of 240 lb per sq in. in less than 5 min. Load variations are dealt with by an automatic governing system which claims to meet demands from half to full load in a matter of some 20 sec. Test figures show a thermal efficiency of 90 per cent exclusive of the feed pump; but the particular feature of note is the maintenance of such a high figure from about a quarter to full load.

The limiting factor of the Velox boiler at present is the range of fuels. Because of the relatively small area of the flue tubes enclosing the water tubes, it is necessary to use either a liquid or a gaseous fuel. In the latter case it is also necessary to clean the gas, and experience with blast-furnace gas had been satisfactory when cleaned to about 0.04 g per cu m. Research work is, however, being carried out, using pulverized fuel, and the result, it is understood, promises success.

In the paper by Adolph Meyer comparative figures are given for three modern passenger liners. These are not reproduced because of lack of space. It is claimed that an increase of steam output from cruising to maximum speed and vice versa is possible in less than 30 sec, which increases maneuverability of the vessel and eliminates waste of fuel in keeping the boiler ready for maximum output. Boilers out of service can be brought into full operation in 6 to 8 min. (This abstract is a composite of two papers read before the Institute of Fuels. Abstracted through *The Steam Engineer*, vol. 3, no. 9, June, 1934, pp. 366, 387–388, 1 fig., *d*)

METALLURGY

Steels for Heat-Treated Gearing

TESTS have been made to determine the wearing qualities of treated steels, but the results are held to be inapplicable to gears. In the first place, most wear tests have been made with abrasives in order to expedite testing; and secondly, no wear-testing machine yet made even approximates the combined rolling and sliding action of gear teeth in action. Tests with gears have been made, but in a sporadic manner, generally by different companies, and the reported results, because of the lack of a common measuring-stick, are hardly comparable.

Most metallurgical authorities agree that tenaciousness, as well as hardness, is required for wear resistance. Just what tenacity is and how to measure it are other questions. In the author's opinion it is a function of the toughness, grain size, and structure, all of which affect, to a greater or lesser extent, the hardness as measured by the conventional methods. As toughness has not been clearly defined, particularly as regards its effect on wearing qualities, it is difficult to state from any of the hardness tests whether or not the steel will wear well.

The following definitions of hardness have been suggested: (*a*) Elastic hardness as measured by the scleroscope; (*b*) tensile hardness as measured by any indentation machine; (*c*) abrasive or cutting hardness as measured by the scratch test.

It would seem that heat-treated steels which give the highest hardnesses as measured by tests (*b*) and (*c*) should wear the best.

Comparing the results of these tests with a microscopic examination of the surface of the steel has given excellent results. In general, it may be stated that steels having a high surface hardness and a fine-grained structure, as shown by the microscope, will wear well.

Impact toughness, as measured by the Charpy or Izod machines, is an indication of the capacity of the steel to withstand shock or impact loads without failure or fracture. It has been receiving more and more attention of late, for it is an excellent indication of the toughness, or more definitely, the lack of brittleness. It should not be used to the exclusion of the static toughness—both should be considered. In general impact strength seems to relate to the grain size (the finer the grain size the higher the impact strength), and though no exact relation has yet been found, it seems to be a function of the reduction of area.

The important matter of control of distortion is discussed as well as the kinds of heat treatment and influence of alloys. Difference of hardness penetration for different steels and comparison of physical properties for different steels are given in the form of curves in the original article. (T. R. Rideout, R. D. Nuttall Works, Westinghouse Elec. & Mfg. Co., in *American Machinist*, vol. 78, no. 11, May 23, 1934, pp. 376–379. Abstract of paper presented at the meeting of the American Gear Manufacturers Association, at Wilkinsburg, Pa., May 4, 1934, *pg*)

MOTOR-CAR ENGINEERING

High-Speed Gas Producer for Motor Vehicles

THIS producer was designed by Maj. J. A. Macdonald and is made by High-Speed Gas, Ltd., 26 Victoria St., S.W. 1, London. It consists essentially of a container of oval cross-section with a filler opening at the top, a clinker discharge hopper at the bottom, and a tuyère and gas outlet on opposite sides. The oval cross-section was selected to reduce the width on the vehicle. There is no separate fuel hopper, shaking grates, or complicated mechanism. The gas is withdrawn at a point only a short distance above the tuyères instead of at the top, and this, in conjunction with the fact that the entering air is mixed with water instead of steam, constitutes the unique features of the apparatus.

The fuel is simply thrown in through the top opening and fills up the space surrounding and between the tuyère and outlet. As a result of the relative position of the tuyère and outlet, the area of the combustion is always small, and is roughly of bulb form with the base of the bulb on the tuyère mouth. The upper part of the container is only slightly warm even after a long run, but the temperature in the incandescent zone is said to exceed 2300 C.

The water necessary to produce the gas is obtained from a small gravity storage tank and after passing through a drip feed on the dash, enters the channel in the tuyère and mixes with the air at a point near the nozzle outlet. The water is admitted deliberately in excess of requirements, and this very unorthodox practise calls for some comment. Any shortage of water results in an immediate falling off in power, and to insure that the exact amount required was supplied under all the varied conditions of running on the road would require very exact regulation. If, however, it can be shown that an excess of water can be supplied without detriment, this difficulty is overcome. It is probable that when a drop of water is carried through the nozzle by the incoming air, a miniature explosion occurs and the water is projected outward to form a zone surrounding the fire, in which the production of carbon monoxide and hydrogen takes place. Any excess of water merely falls by gravity to the lower part of the producer, where it forms a reserve and facilitates the maintenance of the steam zone when the demand for gas is suddenly increased. It thus, in effect, constitutes a reserve which renders close regulation of the supply unnecessary. Should the water be supplied in great excess, the fire will not be affected, but waste will occur as the water will pass into the false bottom of the producer. The fact that the gas is not debased by an excess of water has been established by independent analysis which also showed an entire absence of carbon monoxide.

To start up from cold an oily rag is inserted in the air opening behind the tuyère and ignited, after which the engine is started up on gasoline and allowed to turn over rather rapidly. After a period of about 3 min the gas valve can be opened and the gasoline cock closed. On stopping very little gas is formed after the suction ceases, but as a precautionary measure for use in closed spaces there is a gravity-loaded shut-off valve on the air opening, and any gas formed is forced to pass through a by-pass opening provided with gauze on the Davy-lamp principle.

Service results with these producers are cited in the original article. The only trouble experienced seems to have resulted from the burning of the tuyères, which are made of ordinary water piping. Special heat-resisting steel is now used for plants intended to run on charcoal. Only plants operating on anthracite require water-cooled tuyères. (*Engineering*, vol. 137, no. 3564, May 4, 1934, pp. 512–514 and 516, illustrated, *dA*)

PETROLEUM ENGINEERING (See Electrical Engineering: "Lead Pencil" Motors)

POWER-PLANT ENGINEERING

Rupture of Rivet Holes

THIS comprises a survey of the general literature on the subject. Some of the items are freely available in this country, as, for example, an article on materials for steam-boiler construction by Dr. of Engrg. Jungbluth in *Kruppsche Monatshefte* for July, 1930. Other items have been taken from publications not so available.

Among these is the report issued by the Central Association of Prussian Steam Boiler Supervision Organizations, Vol. 5, pp. 7 and following, prepared by M. Ulrich, of Stuttgart, and entitled "Outages and Duration of Life of Steam Boilers as Determined by the Stressing and Ability to Resist Vibrations of the Materials of Construction." In this report the author tells of observations on 32 boilers, the gage pressure of 18 of which was 13 atm and of 14, 20 atm. He gives a curve showing in terms of time and magnitude the first indications of trouble on these boilers. In the case of the 20-atm gage boilers, 15 per cent of the boilers showed cracks in the riveted seams after five years of service, and 70 per cent after ten years. In the case of the 13-atm gage boilers the curve is very much flatter. It is particularly important to note that when the age of a boiler is stated the duration of the actual operation is also given. From this it would appear that under certain conditions in riveted-seam boilers stresses in the material appear beyond those considered permissible in machinery generally, and such as might come within the limit of the yield point. The structural parts of steam boilers, however, are exposed not only to dynamic but also to alternating stresses. Such alternating or oscillating stresses produce rupture at stresses lying below the elastic limit. The following conclusions are drawn from this investigation.

Where the part of a boiler is not stressed beyond its ability to resist oscillating stresses the forces which produce the stress may act not less than ten million times without creating conditions that would lead to rupture. If, however, the stresses exceed the ability of the material to carry oscillating stresses, the number of possible changes of load and hence potential duration of operation fall off. In fact, the life expectancy of a part of a boiler may be calculated, if information is available as to the stresses and the number of times the load changes per unit of time. However, if the number of times of change of load per day in a certain part is small, the stresses may lie beyond the ability of the material to resist oscillating stresses and yet the part may have a comparatively long life.

In the riveted boilers observed in the course of this investigation ruptures were found chiefly in the riveted joints between the headers and the drums, as well as in the boiler end-plate flanging.

The fact that the duration of life of boilers is so great, notwithstanding their comparatively high stressing, is explained as being due to the circumstance that the number of changes of load on steam boilers per unit of time is comparatively small, and the author derives what he calls an "equivalent number of changes of load," which is $\frac{18{,}500}{\text{number of months}}$. It is claimed that this equivalent number, taken in connection with the number of changes of load determined from tests on oscillations, gives a line which makes it possible to deduce numerically the connection between the stresses in the materials and the duration of the life of the boilers. (Mimeographed bibliography in German. This abstract was taken from *Veroffentlichungen des Zentral-Verbandes des Preussischen Dampfkessel-Uberwachungs-Vereine*, vol. 5, pp. 7, *g*)

Reduction of Boiler Smoke

THIS is a description of a system for smoke elimination, developed in England. The principle on which this eliminator works is (1) very careful stoking and (2) the consumption of such smoke as is produced when the fire is recharged within the furnace by the addition locally of extra air. Several installations have been made and are claimed to be successful. The apparatus for the injection of the air comprises a set of pipes, depending in number upon the size of the boiler, which reach into the furnace for about one-half the length of the grate. They are placed well up in the crown of the furnace so as to be out of the way and are bent at the ends to project the air downward. These pipes are naturally heated by radiation from the fire and consequently provide a supply of hot air. The injectors are on the boiler front, one to each pipe in the form shown in Fig. 5. The amount of steam used and consequently the output of the injector can be regulated by the needle valve.

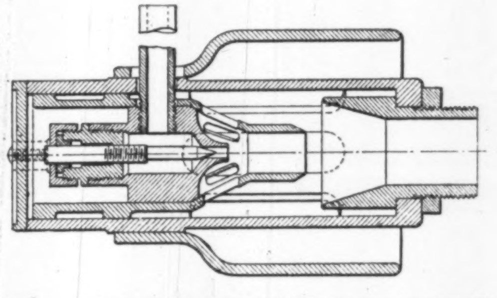


FIG. 5 AIR INJECTOR IN BRITISH SMOKE ELIMINATOR

The cup around the outside of the injector is intended to silence the hissing sound of the jet. The steam consumed by the injectors is said not to exceed 1 per cent of the total output of the boiler. Generally speaking, it is only necessary to keep the eliminators in operation for 3 to 4 min at each firing so that if the boiler is fired, say, every 12 min the apparatus is at work for from 15 to 20 min per hr. An automatic device determines the period during which the jets are in action. It is claimed that with this apparatus a cheaper quality of coal can be used satisfactorily. (*The Engineer*, vol. 157, no. 4085, Apr. 27, 1934, pp. 439–440, illustrated, *d*)

Hopkinson-Moynan Steam Purifier

THIS is a centrifugal type of purifier. On entering the purifier a gyratory motion is imparted to the steam by the vanes in the body of the purifier, with the result that the water and all foreign matter are thrown against the surrounding walls on which are arranged inclined radial serrations. The water and sediment are caught by these serrations and are forced by the gyratory motion of the steam, assisted by gravity, down them into the purifier sump. The inclination of the serrations together with this motion assure a positive self-cleaning action, and therefore the purifier cannot become choked with sediment. On leaving the vanes, the steam continues its gyratory motion, but is deflected upward into the discharge orifice by a specially designed conical deflector plate. This change in general direction does not, however, entail a sudden alteration in direction of flow, since the gyratory motion of the steam becomes a natural vortex which greatly facilitates the change.

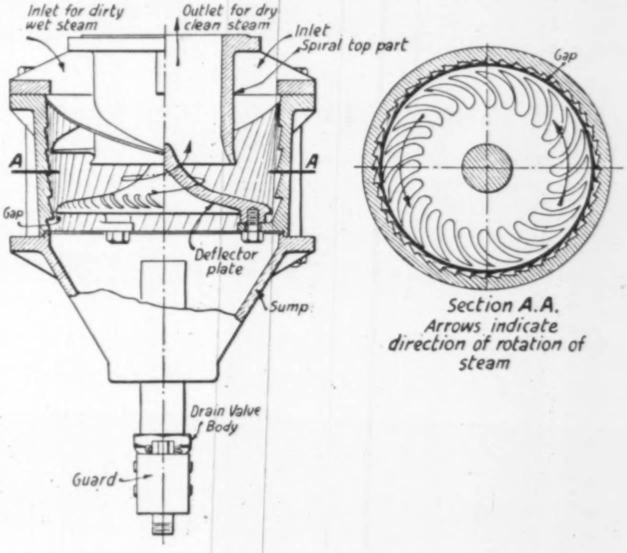

Inlet for dirty wet steam
Outlet for dry clean steam
Inlet
Spiral top part
A
A
Gap
Deflector plate
Sump
Drain Valve Body
Guard
Gap
Section A.A.
Arrows indicate direction of rotation of steam

FIG. 6 HOPKINSON-MOYNAN STEAM PURIFIER

There are curved radial grooves on the surface of the deflector which are provided to catch any further traces of water or dirt which might possibly remain after the thorough purifying treatment encountered by the steam in its passage through the first portion of the purifier. The shape of these grooves is such that a similar self-cleaning and ejecting action takes place as in the serrations of the body. The water is returned from the sump of the purifier to the boiler by means of the overflow pipe and a bronze foot valve, which, in the event of the water level's rising abnormally and covering the valve, prevents water from the boiler from being drawn into the purifier. This valve is designed for easy operation, and will return the water to the boiler, under all conditions, without choking. It is also protected by a shield from surging effects of the water in the boiler. For the periodic removal of the dirt and sludge which accumulate in the sump, a drain pipe is carried from the lowest portion of the purifier to the exterior of the boiler drum, where, by opening a suitable valve, the boiler pressure blows the accumulation out of the drain. (*The Marine Engineer*, vol. 57, no. 680, May, 1934, p. 149, illus., *d*)

CORRESPONDENCE

The Engineer as an Inventor

To the Editor:

In the very interesting and timely article written by Mr. Smith and found on page 263 of the May issue of Mechanical Engineering we find the statement: "In the past, no attempt has been made by the engineering schools to train their graduates in the art of inventing." Now while an examination of the catalogs of the various schools may not disclose anything counter to this statement, some of us former students remember differently, and wishing to give credit where credit is due to pioneer professors of mechanical engineering at Illinois Industrial University, Cornell University, and The Ohio State University, perhaps we can admit that very little has been done by various engineering schools to train their graduates in the art of inventing.

However, if we can admit that the ability to invent does not differ very greatly from ability to do successful research work, then what the schools are now doing and have done in the past will appear in a more favorable light.

Jno. D. Riggs.[1]

Indianapolis, Ind.

A Definition of Wealth

To the Editor:

Many persons are under the impression that a definition of wealth is given by Adam Smith in "The Wealth of Nations." The second edition of that great work, published in the year 1880, proves that impression an error by an editor's footnote that reads, "Smith does not define wealth." Many definitions are given in other books, but none of them is very satisfactory. "Large possessions" and "a comparative abundance of things desired" may do very well as far as they go, but, like all others, do not go far enough to be of practical value, because they give no indication of the nature of things composing wealth, of their source, or of their relation to one another.

Search for information on the subject of how wealth is produced reveals little that is satisfactory and much that inspires thought. Dr. Samuel Johnson, in "The Life of Rasselas," says, "Wealth is nothing but as it is bestowed, and knowledge is nothing but as it is communicated." The thought here is that wealth is a result of movement. A further application of that thought to every day actions of men leads to the decision that wealth is produced by one of two methods, each comprising a series of three movements.

One series consists of (1) accumulation of knowledge having commercial value, (2) exchange of knowledge for money, and (3) exchange of money for knowledge or for material.

The other series consists of (1) accumulation of material having commercial value, (2) exchange of material for money, (3) exchange of money for material or for knowledge.

The third movement is essential to the completion of each method, because, if it were possible for all persons having control of knowledge or of material to exchange it for money and then hoard the money, all production of wealth would cease. That third movement, furthermore, increases demand for knowledge or for material and thereby keeps the process moving. Movement is essential. Knowledge or material will no more produce wealth while not moving than an electric generator will produce electricity while not running.

Money in a safety-deposit vault, goods in a warehouse, knowledge in the brain of a man, and a locomotive standing in a roundhouse, represent dormant power. They are all equally useless until they move. Results of their movement may be useful, useless, or destructive. When a movement of any one of them is directed into useful channels, then wealth production is stimulated. When such a movement ceases, then stimulation of wealth production ceases. When a movement of any one of them is directed into destructive channels, then wealth production is retarded. When such movement ceases, then retardation of wealth production ceases.

Production of wealth is, therefore, neither the achievement of an end nor the maintenance of a condition, but is a continuous process. It is similar to the process of keeping up pressure on a water main or on an electric feeder. Forces of nature keep the process in motion, but results depend on human control and direction of these forces. Their direction to the production of constructive industrial relations between human beings results in gain for all, which stimulates the process. Their direction to the production of destructive industrial relations between human beings results in gain for some through loss by others, which retards the process.

Wealth is a result of constructive industrial relations between human beings.

Under this definition national wealth is the aggregate of the results of constructive industrial relations, less the aggregate of the results of destructive industrial relations, between citizens.

Wealth as thus defined has great power. It is a result of the urge to action within man and that is one of the most powerful forces of nature. That force is maintained by Nature, but she leaves man in full and responsible control of its application. When he applies it to constructive purposes, then he increases his own peace, happiness, and prosperity. When he applies it to destructive purposes, then he decreases his own peace, happiness, and prosperity, and sometimes destroys himself.

Clement F. Street.[2]

Greenwich, Conn.

The Humphrey Gas Pump

To the Editor:

I am pleased that F. du P. Thomson has contributed a paper upon the present status of the Humphrey pump,[3] particularly as it is a subject which is not readily dealt with in technical journals and unless some records of that which has been accomplished are registered, the benefits will not be available for the future, beyond Herbert A. Humphrey's lectures before the Institute of Mechanical Engineers on Nov. 19 and Dec. 3, 1909, and the Manchester Association of Engineers on Nov. 12, 1910.

While in America development has progressed with the piston-type pumps, Messrs. William Beardmore & Company, Ltd., have on this side completed extensive developmental work with the two-cycle pump without the piston.

---

[1] Jun. A.S.M.E.

[2] Mem. A.S.M.E.

[3] See Mechanical Engineering, June, 1934, pp. 337–340.

A very reliable pump was produced which would work for long periods without the involuntary stops associated with the four-cycle pump and with an over-all thermal efficiency of 20 per cent. Unfortunately, the general trade depression which prevailed in about 1927 prevented further developmental work.

One test of interest was with a divided combustion chamber with spherical combustion chamber and a neck orifice similar to that used with a semi-Diesel engine. This pump was extremely flexible and would run for long periods without attention. The combustion-chamber temperatures (measured at the outside) reached 300 to 350 C. This type of pump working with a buffer of inert gas between the combustion charge and the water of varying depth was found to be about half the over-all efficiency of the four-cycle pump, and all attempts to improve it failed, although theoretically much better results should have been obtained.

There is no reason why the two-cycle water-column Humphrey pump should not be a commercial success. In the past probably the necessity of a coal-gas producer militated against its general application, particularly where coal was not available. It is now possible to produce oil-gas plants for working with the Humphrey pump and in this connection Messrs. William Beardmore & Company, Ltd., carried out considerable developmental work.

In America, where there is available in many parts an abundant supply of natural gas, the field for this type of pump is extensive for purposes of raising water, compressing air, or generating electricity.

It is difficult to understand why the simplicity of the Humphrey pump has not been favored by engineers responsible for pumping installations, unless it is because they do not understand thoroughly the working of such a machine.

Since the Great War there appears to have been only one installation of importance, namely, the two pumps built by Messrs. William Beardmore & Company, Ltd., for the South Australian Government for work on the River Murray at Cobdogla. Each pump has play pipes of 5 ft 6 in. diameter and a combustion chamber of 6 ft 6 in. diameter and capable of delivering 24,800 gpm. These pumps are similar to the five at work at the King George V reservoir at Chingford, with certain modifications.

When designing these pumps it was decided not to depart extensively from the Chingford pumps as the risk of failure by so doing was too great, although the cost could have been considerably reduced.

For instance, theoretically and from practical experience a central exhaust valve of large diameter could have been employed instead of the 12 horizontal valves which are coupled up to a common exhaust duct, and fewer mixture and scavenge valves employed.

It is understood that the Cobdogla pumps are giving very good service. In this case the gas is produced from wood fuel.

The Metropolitan Water Board pumps at Chingford have now been at work since 1912 without renewal parts with the exception of a few rubber valve seats, springs, and spark plugs. The advantages of the Humphrey pump for this particular installation are only appreciated when taking into account that the five pumps (four delivering 47 and one 26 million gallons per day) fill the reservoir in six weeks' continuous or twelve weeks' intermittent pumping, and work for one such period annually.

At the official trial in 1913 one of the pumps indicated an overall thermal efficiency of 26.63 per cent. This figure must not be compared with a centrifugal pump with pump horsepower measured at the pump discharge pipe as it includes the frictional losses in the delivery pipe coupling up the water tower to the reservoir. The results of the tests carried out in June, 1913, were published in *Engineering*, Dec. 19, 1913, pp. 835–836.

It is believed that the Chingford pumps today are giving a much better performance although there are no means of obtaining accurate measurement of the quantity of water pumped.

H. D. BUSH.[4]

London, England.

Carburizing With Butane Gas

TO THE EDITOR:

I would like to offer a correction to my paper "Carburizing With Butane Gas," paper No. IS-55-4 in the Transactions, vol. 55 (1933), of The American Society of Mechanical Engineers, page 34, the second and third items under the heading "Results Obtained in Experiments."

Later experience indicates that the control pyrometer used in the experiments described was affected by the entrance and decomposition of the carburizing gas in that part of the furnace, and that the real furnace temperatures, except near the entering gas, was actually about 40 F higher than those given. The ideal operating temperature, therefore, as measured by a thermocouple located so as to be unaffected by the entrance and decomposition of the gas is found to be from 1680 to 1710 F.

Incidentally, six furnace units similar to those described are in 24-hr service (May 1934) giving consistently uniform and wholly satisfactory results, managed as described in the paper referred to.

C. W. SPICER.[5]

Toledo, Ohio.

A.S.M.E. Boiler Code

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Below are given records of the interpretations of this Committee in Cases Nos. 768, and 774 to 778 inclusive, as formulated at the meeting of May 25, 1934. They have been approved by the Council. In accordance with established practise, names of inquirers have been omitted.

CASE No. 768 (*Special Rule*)

Inquiry: Will low-pressure heating boilers fabricated by fusion welding under the requirements of the welding section of the Code for Low-Pressure Heating Boilers meet the Code provisions if the base metal is a high-strength copper alloy of the following chemical and physical properties:

---

[4] 36 Victoria Street, Westminster, S.W. 1.

[5] Vice-President, Spicer Manufacturing Company. Mem. A.S.M.E.

Copper, per cent, approx	96.00
Silicon, per cent, approx	3.00
Manganese, per cent, approx	1.00
Iron, per cent, maximum	0.25
Other elements, per cent, maximum	0.50
Tensile strength, lb per sq in., minimum	52,000
Yield point, lb per sq in., minimum (taken as load producing an extension under stress of 0.50 per cent)	18,000
Elongation in 2 in., per cent	65

The plate is hot rolled and light annealed at 1022 F (550 C), is free from injurious defects and flaws, and has a workmanlike finish.

Can plate thickness for this application be made less than $^1/_4$ in.? Is it permissible to use a pipe size of less than 1 in. if the pipe and fittings used for attaching a water column to a steam-heating boiler are made of brass?

Reply: It is the opinion of the Committee that annealed copper-alloy plates or sheets having the chemical composition and the minimum physical properties specified in the inquiry may be used under Code requirements for heating boiler construction. Under Par. H-70 the allowable working stress of this material would be 5600 lb per sq in.

It will not be permissible to use a lesser plate thickness than specified by Par. H-11 in view of the low yield point of this material.

Par. H-36 establishes the minimum size of pipes connecting a water column to a boiler as 1 in., no matter whether the material is ferrous or non-ferrous.

Case No. 774 (*Special Rule*)

Inquiry: In vertical-fired boilers with outside diameter not exceeding 38 in., and for working pressures not exceeding 250 lb per sq in., is it not permissible to use circular washout openings in the form of couplings welded to the shell in conformity with the present Code requirements and extending through the insulation to the outer steel jacket, said washout openings to be closed with non-ferrous removable plugs?

Reply: It is the opinion of the Committee that for boilers of the type referred to in the inquiry, it is permissible to use circular washout openings not less than 3-in. pipe size.

Case No. 775 and Case No. 776

(In the hands of the Committee)

Case No. 777 (*Interpretation of Par. P-278*)

Inquiry: Par. P-278 of the Code provides that the openings in the boilers for safety valves shall not be less than given in Table P-15. Are outlet openings of connections between the boiler and the safety-valve flange also required to be of a size to comply with Table P-15?

Reply: It is the intent of Par. P-278 to require on tubular boilers, which include horizontal-return tubular boilers, openings, both on the boiler and on the outlet, or outlets of intervening fittings of a size not less than required by Table P-15.

Case No. 778 (*Special Rule*)

Inquiry: Will unfired pressure vessels fabricated by fusion welding under the test requirements of Par. U-69 of the Code meet the Code provisions if the base metal is a high-strength copper alloy of the following chemical and physical properties:

Copper, per cent, approx	95.25
Silicon, per cent, approx	3.25
Zinc, per cent, approx	1.00
Tin, per cent, approx	0.50
Tensile strength, lb per sq in., minimum	52,000
Yield point, lb per sq in. minimum (0.50 per cent of extension under stress)	22,500
Elongation in 2 in., per cent	40
Elongation in 8 in., per cent	25

The plate is hot rolled and annealed, is free from injurious defects and flaws, and has a workmanlike finish.

Reply: It is the opinion of the Committee that annealed copper-alloy plates or sheets having the chemical composition and minimum physical properties specified in the inquiry may be used for the construction of unfired pressure vessels by fusion welding under the general requirements of Par. U-69, the exceptions from which are that the elongation as determined by the free bend test shall not be less than 40 per cent, the tensile strength shall not be less than that of the base metal, and that stress relieving is not required for this kind of annealed material. The operation temperature shall not exceed 406 F. The maximum allowable unit working stress shall not exceed 9000 lb per sq in. for the material, and $(S \times E)$ equals 7200 lb for joints welded as above specified.

Control of Production in a Dynamic Economy

(*Continued from page 475*)

To complete the examples for the automotive industry, Fig. 8 gives the maturity analysis. Several other curves are included in this figure to stress the importance of considering the consumer and the costs of production tendencies when making future plans. It is to be noted that the maturity dates are subject to a rapidly augmented error as extrapolation increases; but the illustrated technique, over that of other methods, seems to reduce such error considerably.

SUMMARY

The theory and the basic method of dynamic production analysis and control of output in industry in the immediate future have been presented as an aid in the management of industrial enterprises. Several examples have been given to show the exact application of the theory to concrete problems.

There has been shown the method of determining (1) the decade trend line, moved forward quinquennially; (2) the secular trend line; (3) the growth-rate and (4) the deceleration of a series; (5) the derived variations of the production series and (6) their trend lines; (7) the estimation of the probable future production; and (8) the extrapolated estimates for the secular tendency as an aid in long-term planning.

Certain factors not within the scope of this paper might be of equal importance to management and this theory does not pretend to include them. It would, therefore, seem that a blind use of this method could not hope to correct all faults in the operation of businesses.

It may be added that the chief danger which besets any system of science is the too-ready manner in which some may apply, or rather misapply, it and so bring discredit on the system. The rules of the method have not been followed, or more often have been misunderstood, and have not been applied with the proper knowledge of the other influencing factors.

Much of this work has been under the supervision of Prof. W. Rautenstrauch, head of the Department of Industrial Engineering, Columbia University, New York.

BOOK REVIEWS AND LIBRARY NOTES

Theory of Elasticity

Theory of Elasticity. By S. Timoshenko. Engineering Societies Monograph Series. McGraw-Hill Book Company, Inc., New York, 1934. Cloth, $5^{3}/_{4} \times 9$ in., 416 pp., 203 figs., $5.

Reviewed by E. O. Waters[1]

THE author who chooses elasticity as his subject has set himself no simple task. His material is not resolved into some orderly or traditional pattern, as it is with many of the older sciences. Nor is it confined within perceptible limits. In spite of the somewhat restricted application that may be claimed for many of the older methods of attack that elasticians have developed, the fact remains that new methods have been, and doubtless will continue to be, discovered, new problems are clamoring for solution, and the very foundations of the science are subjected to criticism and possible revision in the light of researches of the metallurgist and the atomic physicist.

Then, too, there is such a wide choice in methods of presentation. Shall the author arrange his material on historical principles, and, following the example of Todhunter and Pearson, quote directly and in extenso from the great masters, using his own comments and criticisms as a loose sort of cementing medium to bind this tough, durable aggregate into a coherent structure? Or shall he adopt the point of view of the mathematician, state the axioms and fundamental laws on which the science is based, prove his theorems and solve his problems one by one in logical sequence, and organize the whole with an eye to form and order? The outstanding example of this method of treatment is of course Love's comprehensive volume, which has stood for almost half a century as law and gospel to the elastician. This is also the method followed by Doctor Timoshenko; but, whereas Love's point of view is primarily that of the mathematician interested in analysis and searchingly rigorous logic, the present author places the emphasis on the solution of problems, arrived at as simply and directly as possible. This is not to say that the mathematics are skimped, or practical applications magnified; it simply means that the author has set definite limits for the scope of his work, and, within those limits, has chosen to develop the methods of attack and the kind of solutions that would interest the engineer.

The time is certainly ripe for such a book. In the past, the American engineer has been satisfied to use the common formulas of strength of materials for his stress analyses, and, where these were insufficient, to rely on direct tests for his conclusions. But during the past decade or two he has been feeling his way toward more intellectually satisfying methods—partly because of the higher standards of performance that the profession has gradually adopted throughout its rank and file, and partly due to the stimulus of the excellent foreign-trained talent that has found employment in this country. Seven years ago, when an Applied Mechanics Division of The American Society of Mechanical Engineers was being considered, it was freely admitted that, in this country, there was a large gap between mathematics and engineering. At that time, not more than a handful of our engineers cared a fig for the theory of elasticity, nor did the mathematicians who were developing the theory appear to care a fig for the engineer. To quote Professor Love: "Most of the men by whose researches it [the theory] has been founded and shaped have been more interested in Natural Philosophy than in material progress, in trying to understand the world than in trying to make it more comfortable. From this attitude of mind it may possibly have resulted that the theory has contributed less to the material advance of mankind than it might otherwise have done." Today, the engineer realizes that he must know something about this theory; more than that, he finds to his surprise that his own modest mathematical equipment is adequate for understanding it, when it is presented with sympathy for his point of view.

Professor Timoshenko has avoided many needless words and equations by adopting certain well-justified simplifications. At the start, all materials are assumed to be homogeneous and isotropic, thereby reducing the number of elastic constants to two; body forces are, almost without exception, either ignored or reduced to a simple value such as the weight of the material. And practically the entire first half of the volume deals with problems of plane stress and strain, so that the reader is familiarized with the subject by easy steps before he reaches the more difficult field of three dimensions. Throughout the book, the more intricate analyses are set in smaller type, and can be passed over at first reading without detriment to continuity.

The notion of the stress function is introduced at an early point, and is utilized extensively in succeeding chapters as a device for obtaining exact solutions. Due consideration is also given to energy methods, and an entire chapter is devoted to the use of the complex variable and curvilinear coordinates in solving special two-dimensional problems. Lest these mathematical terms alarm the reader, it should be said that the whole chapter is set in small type and may be omitted; moreover, unwary individuals who are intrigued by the subject matter and wish to test their reasoning powers will find that the underlying theory is carefully and logically explained, with specific examples. This painstaking attention to mathematical hurdles that might daunt the engineer who does not keep his calculus well oiled and polished, is characteristic of the author. At one point, however, it would seem that he has taken a trifle too much for granted, and, unfortunately, this is in the chapter on energy methods, which surely merit as attractive an exposition as any portion of the subject. Here, in developing the principle of virtual work, he has seen fit to use the variational calculus. It is to be feared that few engineers in this country will be able to follow this method, and a more detailed explanation of the idea of varying a function, and of the laws to which such variation is subject, introduced at this point, would have been distinctly in order.

The reader who wishes to study the various devices for demonstrating stress patterns will find a brief but adequate account of photoelasticity, hydrodynamic and electrical analogies, and soap-film methods, with numerous references to the source-literature which may or may not be consulted, as he chooses. The book is, in fact, extremely well annotated throughout. The author's previous publications in this country have shown a tendency to lean rather heavily on German and Russian authorities; no such criticism, however, can be made of the present work, which shows a most satisfying familiarity with the whole vast field of elastic-theory literature, regardless of nationality, and an unprejudiced desire to give credit where credit is due.

---

[1] Associate-Professor of Mechanical Engineering, Yale University, New Haven, Conn. Assoc-Mem. A.S.M.E.

In a concluding chapter, Doctor Timoshenko shows how the elastic theory may be extended into the field of dynamics. Compared with the rest of the book, this discussion of waves in elastic solids is a mere hint as to what might be written on the subject; it may be regarded not so much as a conclusion for the present volume as an appetizer for those who wish to go further and explore the vast regions unfolded by a study of problems in vibration.

The author has, no doubt intentionally, omitted certain well-known portions of his subject, such as the theory of shells and the general theory of stability, to mention only two. It is to be hoped that the welcome which this first edition receives will encourage him, in due time, to augment the present volume by including some of these interesting, and, to the engineer, important topics.

Books Received in the Library

Applied Acoustics. By H. F. Olson and F. Massa. P. Blakiston's Son & Co., Philadelphia, 1934. Leather, 6 × 9 in., 430 pp., illus., diagrams, charts, tables, $4.50. The principles of acoustical engineering are presented in this work, which discusses the design, construction, operation, and analysis of modern acoustical and electro-acoustical apparatus. After an introductory chapter on the fundamental acoustic equations, the book treats of the various systems of sound transmission, the fundamental acoustical measurements, laboratory apparatus, microphones, telephone receivers, loud speakers, architectural acoustics, noise, physiological acoustics, and miscellaneous application of acoustics. The book will be useful as a textbook and laboratory manual. The authors are connected with the research laboratories of the R.C.A. Victor Company.

Bericht über die Korrosionstagung 1933 am 14 November 1933 in Berlin Veranstaltet von Deutsche Gesellschaft für Metallkunde, Verein deutscher Ingenieure, Verein deutscher Eisenhüttenleute, Verein deutscher Chemiker. V.D.I. Verlag, 1934. Paper, 6 × 8 in., 79 pp., diagrams, charts, tables, 5 rm. This volume contains the addresses and discussions at a conference on corrosion, held in Berlin in 1933, under the auspices of various societies. Among the questions discussed were the relation between fatigue and corrosion, intercrystalline corrosion in stainless steels, the influence of annealing upon the resistance to corrosion of condenser tubes, and progress in painting aluminum.

Betrieb und Pflege des Kraftwagens. (Sammlung Göschen 1081.) By M. Hüpeden. Walter de Gruyter & Co., Berlin and Leipzig, 1934. Cloth, 4 × 6 in., 147 pp., diagrams, charts, tables, 1.62 rm. Automobile operation, maintenance, and repair are discussed clearly, yet briefly, in this little volume, which covers the subject with sufficient fulness for all ordinary needs.

Cost Accounting for Control. By T. H. Sanders. Second edition. McGraw-Hill Book Co., New York and London, 1934. Cloth, 6 × 9 in., 517 pp., charts, tables, $4. This is a revised and enlarged edition of the author's "Industrial Accounting," brought up to date and in line with the new problems introduced by government control of industry. As in the previous work, emphasis is upon the meaning of costs and their uses in management, rather than upon matters of technical procedure.

Dampfkessel. By H. Netz. B. G. Teubner, Leipzig and Berlin, 1934. Cloth, 6 × 10 in., 108 pp., illus., diagrams, charts, tables, 4.80 rm. This textbook upon boiler construction opens with a section upon theoretical principles, which is followed by sections upon boiler furnaces, boilers, and accessories. The treatment is very concise but covers the subject comprehensively, with special attention to modern developments. The illustrations are unusually good.

Davison's Silk and Rayon Trades. Thirty-ninth edition. 1934. Davison Publishing Co., New York, 1934. Cloth, 5 × 7 in., 607 pp., maps, 5 × 7 in., pocket edition, $5.50; de luxe office edition, $7.50. A convenient directory of manufacturers, jobbers, agents, dealers, etc., covering these trades. Officers, equipment, and capacity are reported for the mills. The arrangement is geographical, with indexes by names and products.

Design of Machine Elements. By V. M. Faires. Macmillan Co., New York, 1934. Cloth, 468 pp., illus., diagrams, charts, tables, $4. Although the conventional method of grouping the material is followed generally in this text, those elements of machines which can be designed without using the more complicated theories of strength of materials are presented at the outset, and the chapters then advance to more difficult work. The subject can thus be studied before strength of materials, or concurrently with it. The book covers usual college requirements clearly and practically.

Dictionary for Metallurgists (Ferrous and Non-Ferrous Metallurgy). Part 2, English-German. By H. Freeman. Otto Spamer Verlag, Leipzig, 1934. Leather, 5 × 7 in., 347 pp., 25 rm. This is an unusually satisfactory dictionary. The vocabulary is large and modern and the translations are very accurate. In addition to metallurgical terms, many general and commercial words are included, so that the book meets all ordinary requirements and will be of use in a wider field than the title indicates. The German-English part appeared in 1933.

Elasticity, Structure, and Strength of Materials Used in Engineering Construction. Developed by the Geometry of Strain and the Energy Function Through Thermodynamic and Chemical Equations in Such Wise That Strength May Be Figured From Chemical Composition of Rolled Metals and the Modification of This Resistance by Mechanical Work. By C. A. P. Turner, privately published by the author at 300 Builders Exchange Building, Minneapolis, Minn., 1934. Cloth, 6 × 10 in., 416 pp., illus., diagrams, charts, tables, $6. The conclusions that Dr. Turner has drawn from many years' study of the theory of resistance are indicated by the title of this book, in which his matured views are presented in detail. Considerable portions of his earlier book, "Elasticity and Strength of Materials," reappear in this one, but the theoretical framework of the subject has been further developed.

Engineering Drafting. By W. G. Smith. McGraw-Hill Book Co., New York and London, 1934. Cloth, 6 × 9 in., 236 pp., illus., diagrams, tables, $2.25. A course for the beginner which aims to develop, in addition to skill as a draftsman, independent thinking and initiative. Part one presents the fundamentals of the subject; part two, its applications to machine, airplane, and pictorial drafting.

Spannungsverteilung in Konstruktionselementen. By E. Lehr. V.D.I. Verlag, Berlin, 1934. Paper, 8 × 12 in., 64 pp., illus., diagrams, charts, tables, 7.50 rm. During the past twenty years, much attention has been paid to the distribution of stresses in machinery. Special methods of investigation by means of models, optical measurements, etc., have been developed, and numerous reports have been published which clarify the problem. These reports, however, are widely scattered and often understandable only to specialists. The present publication summarizes the results of these investigations in form for practical use. Methods for determining stress distribution are also described. There is a bibliography. The book will be useful to designers and machine builders generally.

"V.D.I. Jahrbuch 1934." Die Chronik der Technik. V.D.I. Verlag, Berlin, 1934. Paper, 6 × 8 in., 189 pp., 3.50 rm. The Jahrbuch is intended to supply a need not satisfied by indexes and abstract journals, the need for a systematic account of new developments in engineering and related fields which will enable the engineer to keep abreast of current advances. It contains concise reviews by various specialists, upon applied physics, materials, fuels, boilers and firing, hydroelectric and steam plants, transport, building, refrigeration, lighting, etc., during 1932 and 1933. These are accompanied by extensive references to original papers and provide a valuable approach to late developments. The Jahrbuch continues the "chronicle" which formerly appeared in the *V.D.I.-Zeitschrift*.

Walzwerkswesen. (Handbuch des Eisenhüttenwesens, Vol. 2.) By J. Puppe and G. Stauber. Julius Springer, Berlin; Verlag Stahleisen, Düsseldorf, 1934. Cloth, 8 × 11 in., 524 pp., illus., diagrams, charts, tables, 110 rm. The first volume of this great treatise on rolling-mill practise appeared in 1929 and dealt with its history, economic and theoretical problems, and other general matters. The present volume begins the account of special types of rolling. Lengthy sections are devoted to the rolling of blooms, slabs, and preliminary shapes, of billets and sheet bars, of heavy shapes and bars, of beams and of light sections, wire, bands, and strips. A number of specialists have collaborated on each subject. The treatment is very practical and complete and good bibliographies are provided. The book is more comprehensive than any other on its subject.

WHAT'S GOING ON

Nominations for Officers of A.S.M.E., 1934–1935

AT THE Semi-Annual Meeting of The American Society of Mechanical Engineers at Denver, Colo., June 25 to 28, 1934, the Nominating Committee reported the following nominations for officers of 1934–35, to be voted on by letter ballot in the early fall.

For president, Ralph E. Flanders; for vice-presidents, James H. Herron, Eugene W. O'Brien, and Harry R. Westcott; and for managers, Bennett M. Brigman, Jiles W. Haney, and Alfred Iddles. Brief biographical sketches of the nominees follow:

Ralph E. Flanders

RALPH E. FLANDERS, nominated for the office of president of The American Society of Mechanical Engineers, is president of the Jones & Lamson Machine Company, Springfield, Vt. He was born at Barnet, Vt., September 28, 1880, and was educated at the Central Falls (R.I.) High School. His early experience in machine design and construction was received at Brown & Sharpe Manufacturing Company, Taft-Pierce Manufacturing Company, International Paper Box Machine Company, and General Electric Company. After four years as associate editor of *Machinery* and two years as sales engineer with the Fellows Gear Shaper Company, he joined the Jones & Lamson Machine Company in 1912 as manager of the Fay Lathe Department. In 1914 he was made general manager and in 1933 president of the company.

Mr. Flanders is regarded as a national authority on machine design and construction, especially on the engineering problems of screw threads and thread grinding. His 1924 A.S.M.E. paper on "The Design, Manufacture, and Production Control of a Standard Machine" brought a successful solution to the problem of building machinery economically at widely varying rates of demand.

Mr. Flanders has devoted a large amount of time and effort to the welfare of his profession, serving on many committees of The American Society of Mechanical Engineers. Since 1921 he has been a member and since 1930 chairman of the Sectional Committee on Standardization and Unification of Screw Threads. He represented the A.S.M.E. on the National Screw Thread Commission from 1919 to 1924. He has been a member since 1926 and chairman since 1930 of the Special Research Committee on Strength of Gear Teeth. He served on the Publications Committee from 1918 to 1924 and acted as chairman in 1925 through 1928. He was a manager of the Society from 1926 to 1929 and vice-president in 1930 and 1931.

As a delegate of the A.S.M.E. to the American Engineering Council in 1924–25 and from 1932 to date he has been active in the Public Works program of the Council, and was a member of its Committee on Government Reorganization. As chairman of its Committee on the Relation of Consumption, Production, and Distribution he has been in a position of strong leadership.

Serving as president of the National Machine Tool Builders Association in 1924, Mr. Flanders presented a presidential address that dealt with current economic problems. In this address he pointed out the importance of the transition from the economy of need to the economy of plenty, a contribution of great importance to economic thinking of the times. His address before The American Society of Mechanical Engineers in December, 1930, on "Engineering, Economics, and Social Well-being" marks his entry into a course of economic study, discussion, and writing that ha brought him to the forefront of leadership in his field and led to his selection as a member of the American Engineering Council's Committee on the Relation of Consumption, Production, and Distribution, already mentioned. He is also a director of the Social Science Research Council.

Upon the passage of the National Industrial Recovery Act and the organization of the National Recovery Administration, Mr. Flanders was called into service as a member of the Industrial Advisory Board. He is also a member of the Business Advisory and Planning Council appointed by Secretary of Commerce, Daniel C. Roper. At the conference of the industrial leaders engaged in the administration of various codes for industries held in Washington the first week in March, his grasp of the basic industrial and economic problems at the present time enabled him to step into a position of leadership in the discussion, which had a profound effect on the deliberations of that important occasion.

Mr. Flanders has written on a wide range of subjects. In his early career his papers and books on gears and gear machinery were highly regarded. Later his discussions of industrial and economic problems have appeared in a wide range of magazines and his recent book, published in 1931, on "Taming Our Machines" was very well received.

Mr. Flanders was granted the degree of Mechanical Engineer by Stevens Institute of Technology in June, 1932, and the degree of Master of Arts by Dartmouth College the same year. In June, 1934, he was honored with the degree of Doctor of Science, by Middlebury College, and Doctor of Engineering, by Brooklyn Polytechnic Institute. He is lecturer at the Tuck School of Business Administration at Dartmouth College and has spoken before many groups of economists, engineers, and industrialists on subjects dealing with economics, engineering, and related problems.

James H. Herron

JAMES H. HERRON, nominated for the office of vice-president of The American Society of Mechanical Engineers, is president of the James H. Herron Company, Cleveland, Ohio. He was born in Girard, Pa., on January 4, 1875. In 1909 he received the degree of B.S. in mechanical engineering from the University of Michigan.

From 1889 to 1895 he served as an apprentice with the Sterns Manufacturing Company, Erie, Pa. From 1895 to 1909 he was engaged in engineering work with the Erie City Iron Works, Erie, Pa., the University of Michigan, the Cambria Steel Company, Johnston, Pa., the Bury Compressor Company, Erie, Pa., the Motch & Merryweather Machinery Company, Detroit, Mich., and the Detroit Steel Products Company, Detroit, Mich. Since 1909 he has been president of the James H. Herron Company, engineers and chemists, of Cleveland, Ohio. In addition, he is president of the Paragon Laboratories, and director of the Baldwin Farms Land Company, the Period Printing Company, and the National Engineering Inspection Association.

Mr. Herron is the inventor of the air-compressor inlet-valve unloader and of numerous devices for use with air compressors and metallurgical furnaces. He is the author of articles on metallurgical subjects published in technical periodicals, and was associate editor of Hool and Johnson's "Handbook of Building Construction" and Hool and Kinne's "Structural Engineers Handbook Library."

As a member of The American Society of Mechanical Engineers, he has been active in the Cleveland Section. He served on the Committee on Local Sections from 1917 to 1922, and was a member of the Council from 1922 to 1925. He is also a member of the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Chemical Society, the American Society for Testing Materials, the British Iron and Steel Institute, the Society of Automotive Engineers, the American Concrete Institute, the American Association for the Advancement of Science, and the Cleveland Engineering Society, of which he was president from 1917 to 1918. His civic services have included the presidency of the Cleveland Heights Board of Education, and directorship in the engineering division of the Cleveland War Industries Board and the Municipal Research Bureau of Cleveland. He is a member of the Committee on Professional Conduct of the A.S.M.E.

Eugene W. O'Brien

EUGENE WILLIAM O'BRIEN, nominated for the office of vice-president of The American Society of Mechanical Engineers, is editor of the *Southern Power Journal*, Atlanta,

Nominated for
A.S.M.E. OFFICERS IN 1935

For President

RALPH E. FLANDERS

For Vice-Presidents

H. R. WESTCOTT

E. W. O'BRIEN

J. H. HERRON

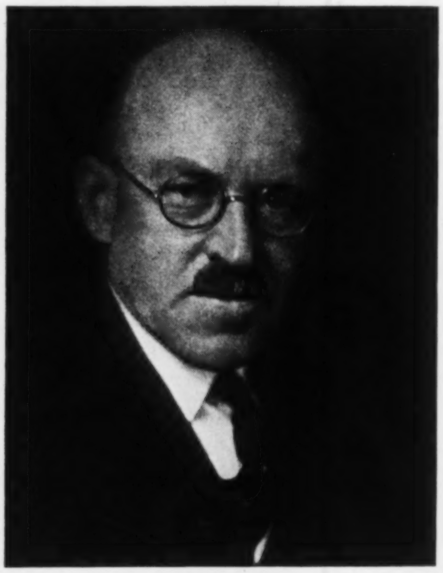
For Managers

ALFRED IDDLES

B. M. BRIGMAN

J. W. HANEY

Biographical sketches of the candidates will be found on pages 503–506 of this issue.



RALPH E. FLANDERS

HARRY R. WESTCOTT

EUGENE W. O'BRIEN

JAMES H. HERRON

ALFRED IDDLES

BENNETT M. BRIGMAN

JILES W. HANEY

Ga. He was born at West Warwick, R. I., June 20, 1897.

His early education was received in the public schools of his home town. Later he entered Brown University, from which he was graduated in 1919 with the degree of B.S. in electrical engineering. Two years later the degree of Sc.M. in mechanical engineering was conferred upon him by the same university; and in 1925 the degree of M.E. by Yale University.

From 1918 to 1922 he was a member of the engineering faculty at Brown University, leaving to accept a similar position at the Sheffield Scientific School, Yale University. During his period of service as college instructor, he spent much of his time in consulting engineering, serving part time in a number of consulting offices in New England, and undertaking independent commissions in the fields of mechanical, electrical, and power design and construction.

In 1925 he left the Sheffield Scientific School to join the organization of Jenks & Ballou, engineers, Providence, R. I. There he engaged in the wide variety of investigation, design, and supervision work handled by that office, specializing in mechanical and power projects. He became editor of the *Southern Power Journal* in 1927. Mr. O'Brien has been active in the work of the A.S.M.E. local sections in Providence, New Haven, and Atlanta. He has served on the A.S.M.E. Committee on Relations With Colleges, and in 1931 he was elected a member of Council as manager of the Society.

He is a member of technical organizations, including Sigma Xi, the American Academy of Political and Social Science, and the American Society of Refrigerating Engineers. He is also a member and secretary of the Smoke Abatement Commission of Atlanta.

Harry R. Westcott

HARRY R. WESTCOTT, nominated for the office of vice-president of The American Society of Mechanical Engineers, is president of Westcott & Mapes, Inc., consulting engineers and architects, of New Haven, Conn. He was born at Dighton, Mass., in December, 1881, and was educated at the Providence Technical High School, the Rhode Island School of Design, Brown University, where he studied electrical and mechanical engineering, and Yale University. For several years he was connected with the Atlantic Mills, Providence, R. I., the A. D. Julliard Company, New York City, and the Hood Rubber Company, Watertown, Mass. At the time he became a member of the A.S.M.E. in 1915 he was superintendent of construction of the United Illuminating Company, of New Haven, Conn. Shortly thereafter he organized the consulting engineering firm of Westcott & Mapes, Inc., in New Haven, and has since been responsible for the erection of many power plants and office and industrial buildings, and has engaged in general consulting work.

Mr. Westcott has been prominent in the civic life of his community. He has served as a director of the New Haven Y.M.C.A. and as a director of the New Haven Chamber of Commerce, and chairman of its Industry Committee.

Mr. Westcott has also been active in the work of the A.S.M.E. He served on the executive committee of the New Haven Section from 1921 to 1924, inclusive. He was also instrumental during that period in the organization of the New Haven Machine Tool Exhibition, which ran seven exhibitions of machine tools at Mason Laboratory, Yale University. This unique undertaking was successfully managed by a committee representing the faculty of Sheffield Scientific School, the New Haven Chamber of Commerce, and the New Haven Section, A.S.M.E., Mr. Westcott serving as its chairman throughout the seven years during which it was conducted. The undertaking grew until it completely taxed the facilities of Mason Laboratory, upward of 20,000 persons visiting it in four days.

Mr. Westcott later served on the A.S.M.E. Standing Committee on Local Sections from 1925 to 1931. In 1931 he was elected a manager of the Society, and since 1932 he has headed up the important work of the Committee on Policies and Budget which is engaged in an exhaustive study of the aims and organization of the Society. In June, 1934, he was honored by receiving the degree of Mechanical Engineer from the Stevens Institute of Technology.

Bennett M. Brigman

B. M. BRIGMAN, nominated for the office of manager of The American Society of Mechanical Engineers, is dean of the Speed Scientific School of the University of Louisville. Dean Brigman was born in Louisville, Kentucky, February 25, 1881. He was educated at the University of Kentucky and the University of Louisville, receiving the degree of B.S. in 1908 and M.S. in 1912 from the University of Louisville. During the summer of 1915, he did post-graduate work at the University of Wisconsin.

Dean Brigman was engineer of tests on the L. & N. R.R. from 1902 to 1904. He began his teaching career as instructor of manual arts at the University School of Louisville in 1904. He served as an instructor in the du Pont Manual Training High School, Louisville, and successively as instructor and assistant professor of physics, and professor of engineering and drawing in the University of Louisville. When the Speed Scientific School was organized, 1923–1924, he became dean.

Dean Brigman has also practised as a consulting engineer. He organized and developed the Speed Scientific School for teaching civil, chemical, electrical, and mechanical engineering on a modified cooperative plan. He has written numerous educational and engineering papers, reports, pamphlets, research pamphlets, and magazine articles.

Dean Brigman has been active in the affairs of the A.S.M.E. both locally and nationally. He is a member of the American Institute of Electrical Engineers, the American Society for Testing Materials, the Society for the Promotion of Engineering Education, which he served first as a member of the Council and later as a vice-president, the American Association of University Professors, of which he is an honorary member, the American Association for the Advancement of Science, the Society of American Military Engineers, and the Kentucky Educational Association. He is the advisory engineer on the Louisville Loan Agency of the R.F.C., and a member of the Jefferson County Consumers' Council of the NRA. He is past-president of the Engineers and Architects Club of Louisville, the University Club, and the Optimists.

He has been chairman of the Louisville Local Section since 1926.

Jiles W. Haney

JILES W. HANEY, nominated for the office of manager of The American Society of Mechanical Engineers, is professor of mechanical engineering at the University of Nebraska, Lincoln, Neb. He was born in Guin, Ala., November 17, 1886. He attended the University of Missouri where he received the degree of B.S. in mechanical engineering in 1913, of M.E. in 1914, and of A.M. in 1915.

From 1915 to 1916 Professor Haney was chief engineer of the Commerce Power & Building Company. He became an instructor at the University of Missouri in 1916. From 1916 to 1918 he was instructor at the Pennsylvania State College. In 1918 he joined the faculty of the University of Nebraska, where he has been chairman of the department of mechanical engineering since 1927.

During the War he was civilian instructor, U. S. Army Auto Mechanic and Truck Driving School, Pennsylvania State College, and is now a major, Reserve Officers Corps, U. S. Army.

Professor Haney has served the A.S.M.E. as a member of the Committee on Local Sections since 1928 and is now its chairman. He was chairman of the Nebraska Section from 1922 to 1926. He is also a member of the Society for the Promotion of Engineering Education, Sigma Tau, and Sigma Xi. He was president of the Optimist Club of Lincoln, 1930, of the Kansas-Nebraska Section of the S.P.E.E. from 1930 to 1931 and of the Engineers Club of Lincoln, 1925. He is co-author of "The Transmission of Heat Through Boiler Tubes" (Engineering Experimental Bulletin of the University of Missouri).

Alfred Iddles

ALFRED IDDLES, nominated for the office of manager of The American Society of Mechanical Engineers, is vice-president of United Engineers & Constructors, Inc., Philadelphia, Pa.

Mr. Iddles was born in Allegan Co., Mich., Dec. 1, 1889, and received his engineering education at Michigan State College where he received a degree of B.S. in mechanical engineering in 1912 and of M.E. in 1917. From 1912 to 1914 Mr. Iddles was foreman and then assistant superintendent of gas-manufacturing plants for the Michigan Light Company at Jackson and Flint, Michigan. For the next three years he was instructor and then assistant professor of mechanical engineering at Michigan State College and while teaching engaged in consulting practise. During the War he served as captain in the chemical warfare service, being assigned to poison-gas plant at Edgewood Arsenal in charge of the public-utility service for this manufacturing plant. He was a fuel engineer with U. S. Bureau of Mines immediately following the War and in 1920 became associated with Day & Zimmermann, Inc., in Philadelphia, as power engineer, and later as chief engineer. At present he is executive vice-president of United Engineers & Constructors, Inc., and of their subsidiary companies in Canada and South America.

During the years 1929 to 1933 Mr. Iddles was a member of the executive committee of the A.S.M.E. Power Division. He served as its chairman in 1932. In 1931 he was apponited to the A.S.M.E. Standing Committee on Standardization. He now represents the Society on the Sectional Committee on Pressure Piping and is chairman of the Subcommittee on Gas and Air Piping. He is a member also of the Sectional Committee on Drawing and Drafting-Room Practise.

He is co-author of a textbook, "Steam Engine Design," and the author of many papers appearing in technical periodicals. Mr. Iddles is a member of Philadelphia Engineers Club and has been active in the work of the Philadelphia Section of the A.S.M.E.

A.S.M.E. Meets at Denver, Colo.

THE 1934 Semi-Annual Meeting of The American Society of Mechanical Engineers was held in Denver, Colo., June 25 to 28, with headquarters at the Cosmopolitan Hotel. A complete program of the meeting was published in the June issue of MECHANICAL ENGINEERING. The attendance of 240 included four members of Council, Prof. John A. Hunter, of the University of Colorado, Alex. J. Dickie, of San Francisco, Calif., H. L. Doolittle, of Los Angeles, Calif., and Harry R. Westcott, of New Haven, Conn. Because of his duties as recently appointed Regional Supervisor of the Home Owners' Loan Corporation for the southeastern district, President Doty was unable to attend the meeting. He sent a telegram of greeting and appointed Messrs. Doolittle and Westcott to represent him. Mr. Doolittle presided at the business and other meetings and Mr. Westcott spoke for the president at the dinner.

At the business meeting invitations from several local sections for the Society to hold next year's semi-annual meeting in cities in their districts were received. It was announced by Calvin W. Rice, secretary, A.S.M.E., that Cincinnati would probably be the scene of next year's meeting, a prediction that was confirmed by the action of Council at its meeting at Purdue the following week.

The high point of the technical sessions was Reclamation Bureau Night at which Dr. Elwood Mead, Commissioner of the U. S. Bureau of Reclamation, and engineers of the Bureau described the mammoth engineering project under construction at Boulder Dam and the mechanical features of the hydraulic and hydroelectric equipment. The session, which was illustrated with slides and motion pictures, was held at the Broadway Theater and attracted an audience of 1500. Dr. Mead was presented a beautiful floral tribute. Inasmuch as there are about 600 Reclamation Bureau engineers in Denver, which is the headquarters of the engineering design work on the project, interest in the papers and the pictures was keen. Three of the papers presented, those by Messrs. Kinzie, Winter, and McClellan, appeared in the July issue of MECHANICAL ENGINEERING, and the fourth, by Messrs. Day and Bier, will be found in this issue.

Several papers presented at other technical sessions will be found in the June issue, and the papers by Anderson and Eksergian, which were preprinted for the Railroad Division Session, will appear in an early issue of the A.S.M.E. Transactions.

Tuesday evening was the occasion of the banquet at which Thomas Beale Stearns, engineer, Stearns-Roger Manufacturing Co., Denver, Colo., acted as chairman. A pleasant feature of the program was the presentation of the A.S.M.E. Fifty-Year Membership Medal to Mr. Stearns. Harry R. Westcott presented President Doty's greetings. The banquet speaker was Capt. Irving O'Hay, soldier of fortune, whose humorous recital of his experiences in many parts of the world and in many armies greatly entertained his hearers. Guests at the banquet included Governor Johnson, of Colorado, and Mayor Begole, of Denver, both of whom delivered addresses of welcome.

Announcement was made at the meeting of the Nominating Committee's report on nominations. Ralph E. Flanders, of the Jones and Lamson Machine Co., Springfield, Vt., was nominated for the office of president. The other nominations were, for vice-presidents, Eugene W. O'Brien, of Atlanta, Ga., James H. Herron, of Cleveland, Ohio, and Harry R. Westcott, of New Haven, Conn.; for managers, B. M. Brigman, of Louisville, Ky., Alfred Iddles, of Philadelphia, Pa., and J. W. Haney, of Lincoln, Neb. Brief biographical sketches of the officers nominated appear in this issue.

Enthusiastic reports from members of the A.S.M.E. attending the Denver meeting attested the high quality of the program and the painstaking and efficient manner in which the details were planned and executed. The chairmen and members of the local committees that were responsible for such a memorable meeting have earned the admiration and thanks of all who were able to attend and are entitled to the gratitude of the less fortunate who will find in the published papers an interesting and valuable record of engineering work in the Denver district.

The excursion and entertainment features of the meeting added greatly to the pleasure of members and guests, particularly those from the East who were unfamiliar with the scenic beauties and the industrial development of the Denver district. A program of activities for the women guests provided interesting diversions for them during the technical sessions.

The General Convention Committee was under the general chairmanship of Arthur Halliwell, Prof. John A. Hunter, honorary chairman, and F. A. Lockwood, C. R. Ahlquist, and George Richter, members. The special committees were as follows: *Technical Events*, F. H. Prouty and H. B. Barnes. *Ladies' Entertainment and Information*, Mrs. H. B. Barnes. *Finance*, C. R. Ahlquist, L. D. Crain, A. Halliwell, John A. Hunter, F. A. Lockwood, D. J. Nevill, F. H. Prouty, and G. Richter. *Publicity*, Dan McQuaid. *Excursions and Entertainment*, R. W. Morton. *Student Branches*, John A. Hunter. *Hotels and Registration*, H. B. Barnes. *Reception*, John A. Hunter and R. A. Hake.

Diesel Subjects Discussed at State College

MORE than 200 persons attended the Seventh National Oil and Gas Power Meeting, June 20 to 23, at Pennsylvania State College, State College, Pa., under the joint auspices of the A.S.M.E. Oil and Gas Power Division, the A.S.M.E. Central Pennsylvania Section, and the College. In accordance with

Semi-Annual Meeting

AT THE A.S.M.E. SEMI-ANNUAL MEETING AT DENVER the plan of previous meetings, the program consisted of five technical sessions with considerable opportunity for recreational features. The complete program was printed in the June, 1934, issue of MECHANICAL ENGINEERING.

The technical program opened on Wednesday morning with T. B. Heltzel's paper on "Factors Influencing the Regularity of Jerk-Pump Injections." Among the subjects discussed was the development since the preparation of the paper of an optical indicator that shows the motion of the stem of a nozzle valve. This was designed by Professor de Juhasz of the Pennsylvania State College for use in the investigation of the performance of Diesel fuel-injection systems. In the Wednesday afternoon session two papers were presented: "The Design of a Fuel-Injection Pump," by C. A. Alden, and "Honing of Cylinder Liners and Pump Barrels," by K. W. O'Connor. These papers provoked lively and interesting discussion.

On Thursday morning Dr. Paul H. Schweitzer, of the Pennsylvania State College, presented a paper entitled "The Penetration of Oil Sprays in Dense Air." His paper described research work being done at the College. The value of this research work to industry was highly commended. The remainder of the session was given over to a discussion of high-speed Diesel engines, led by A. B. Trieber, who outlined the problems and showed numerous slides illustrating various combustion-chamber designs. The Hesselmann low-compression engine which uses Diesel fuel oil injected fifty degrees before top dead center and also spark-plug ignition was discussed. The compression ratio recommended was about 10 to 1, resulting in an engine of somewhat lighter construction than the full Diesel. There was also a report on the development of Diesel locomotives in Europe with illustrations of early models and an explanation of the troubles that led to changes in design.

Friday morning's session was opened with a paper by L. M. Goldsmith on "Diesel-Electric Pipe-Line Pumping Stations." In the discussion of this paper there were many comments on piston rings and especially the effect of their position on the consumption of lubricating oil. The paper contained a number of interesting curves of oil consumption. The author gave flexibility and cost as his reasons for using the Diesel-electric drive. The Diesel Power Cost Report was presented by M. J. Reed, secretary of the committee, and discussed by L. H. Morrison, who presented a statistical analysis of last year's report. The report this year contained the 1933 cost data on 156 plants for 1933; the 1932 report included 140 plants. In the present report the three former tables of data on fuel oil, and maintenance costs, have been combined into one.

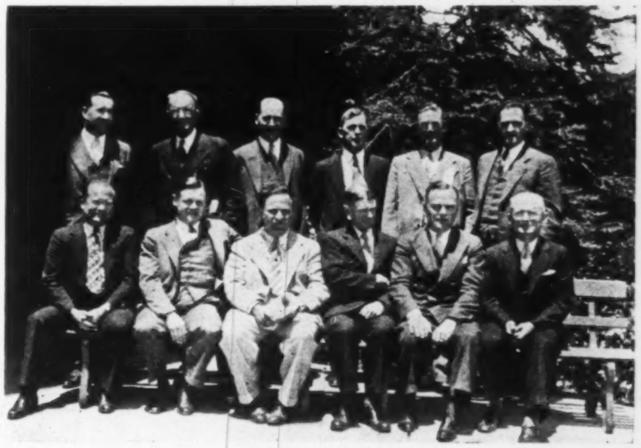
At the final session on Saturday morning two papers were presented, one by T. B. Rendel on "The Situation Concerning Diesel Fuel Oil," and the other by W. G. G. Godron on "Wear of Piston Rings and Liners Influenced by Piston-Ring Design."

There were some twenty exhibits of Diesel-engine equipment and accessories on display in connection with the meeting. Several of the exhibitors gave short interesting talks at the close of the technical session on developments in the accessory field.

Preprints of the following papers were made available by the Pennsylvania State College in cooperation with the Oil and Gas Power Division: Heltzel, Alden, Connors, Schweitzer, Goldsmith, Rendel, and Godron. These papers will later be published in a bulletin of the Pennsylvania State College which may be secured at a reasonable price. The preliminary Report on Diesel Power Cost for 1933 is now available to members at a price of $1. This report will probably be printed in the A.S.M.E. Transactions in 1935.

A.S.M.E. Aero-Hydraulic Meeting, Berkeley, Calif., Well Attended

THE joint Aeronautic-Hydraulic Division meeting, June 19 to 21, convened at Berkeley, Calif., during the week devoted to the summer meeting of the American Association for the Advancement of Science. The sessions were recognized as those of Section M of that association. The value of affiliation with the A.A.A.S., as far as the engineering societies are concerned, lies chiefly in the opportunities afforded for engineers to come into direct contact with those who are responsible for the progress of the sciences upon which engineering depends. This was exemplified at the Berkeley meeting in many ways. The opening public lecture of the association by Prof. Joel H. Hildebrand on "The Liquid State" was significantly related to the two sessions of the following day which were devoted by the Aeronautic and Hydraulic Divisions of the A.S.M.E. to programs on the problems of fluid mechanics. The lecture served as an admirable introduction to the subject.



GROUP ATTENDING AERONAUTIC-HYDRAULIC MEETING

Front row, left to right: E. C. Barkstrom, chairman of the Los Angeles Section; Elmer A. Sperry, first vice-chairman, Aeronautics Division; A. L. Klein, California Institute of Technology; B. M. Woods, University of California, chairman of the Conference; E. E. Aldrin, chairman of Guggenheim Medal Fund Board; J. E. Younger, University of California. *Back row, left to right:* Richard H. Smith, Massachusetts Institute of Technology; E. P. Leslie, Stanford University; A. F. Bonnalie, Boeing School of Aeronautics; W. R. Jones, Oregon State College; H. B. Langille, University of California; S. R. Dows, chairman of the San Francisco Section.

TECHNICAL PROGRAMS

The engineering features of the Berkeley meeting included not merely the sessions of the Aeronautic and Hydraulic Divisions of the A.S.M.E. but also those of the Section of Hydrology of the American Geophysical Union, of the Pacific Coast Section of the American Society of Agricultural Engineers, and of the Western Inter-State Snow Survey Conference. The Institute of the Aeronautical Sciences joined in sponsoring the meetings of the Aeronautic Division and was represented by Professors Elliot G. Reid, of Stanford University, and B. M. Woods, of the University of California.

So far as is known, the plan to devote the opening day to joint sessions on the subject of fluid mechanics marks a new development. An examination of the program will show that the papers covered many types of flow and the problems associated with them. Without reviewing details of the program, which was published in full in the June issue of MECHANICAL ENGINEERING, it is interesting to note that the turbulence problem in its technical aspects was reviewed by von Kármán, dynamical similarity in open-channel flow by Bakhmeteff, and that other speakers discussed such widely varying topics as flow in soils, the aerodynamics of wing sections, and cavitation studies. The unifying role of fluid mechanics in the treatment of these many problems was apparent and significant.

The meetings of the Hydraulic Division on the following days were devoted to sessions on the status of the pump industry, hydraulic machinery, and flow in pipes. Those of the Aeronautic Division were devoted to structures, transport and management, and engines and propellers.

Among the special events, the first was a public address on "The Automatic Pilot," delivered by Elmer A. Sperry as a general feature of the program of the American Association for the Advancement of Science. This was provided in response to the general interest in the contribution of the gyroscope to the navigation of ships as well as to the avigation of airplanes. The lecturer ably presented the latest developments in the use of the gyroscope as well as some of the problems as yet unsolved.

GUGGENHEIM MEDAL AWARDED TO W. E. BOEING

The meeting was honored by the inclusion on the program of the presentation of the Guggenheim medal for 1934 to William Edward Boeing, of Seattle. This occurred at a dinner at the Engineers' Club of San Francisco under the joint auspices of the A.S.M.E., the Institute of the Aeronautical Sciences, and the American Association for the Advancement of Science, on Wednesday evening, June 20. The formal presentation was made by Major E. E. Aldrin, president of the Daniel Guggenheim Medal Fund, Inc., and chairman of the Committee on Award. Among the many outstanding achievements in aviation, resulting from the pioneering and leadership of Boeing, the following may be mentioned as most significant. Fifty-six different types of airplanes have been built by his company during the seventeen and one-half years just past for commercial, private, and military use—a total of more than 1800 airplanes. The company was in many ways a pioneer. It was the first to use air-cooled engines for commercial and defense planes and the first in the United States to adopt the steel-tube fuselage developed by Fokker. The Boeing Transport Company was the first to fly passengers at night on regular schedule over long distances, the first to operate tri-motored passenger transports over long distances and at night, and the first to be fully equipped with two-way radio telephone. Further, the Boeing plant has built the greatest number of pursuit aircraft produced by any manufacturer since the War. These army and navy fighting planes have incorporated features of design and construction which, according to air-corps officers, have enabled this country to possess the fastest single-seater air-cooled standard military aircraft. The citation read: "For successful pioneering and achievement in aircraft manufacturing and air transport."

COOPERATION INSURED SUCCESS

The A.S.M.E. is indebted to all of its Pacific Coast Sections and to the Universities of the coast for the whole-hearted cooperation which made the meeting significant. It will be noted in the program that prominent universities of Washington, Oregon, California, Arizona, etc., were represented. In the same spirit the program was arranged so that the Aeronautic-Hydraulic sessions of the first two days were on the Berkeley campus of the University of California while those of the third day convened on the campus of Stanford University.

The important excursion of the meeting was that to the Sunnyvale Air Base and the *Macon* on the afternoon of June 21 following the morning sessions at Stanford University. Those making the excursion as guests of the United States Navy had an excellent opportunity to note the interesting and complex problems involved in operating an important airship base, as well as the privilege of inspecting the *Macon* itself.

Members attending the meetings were especially grateful to the program committee for its success in preprinting and binding into a single cover the entire set of papers presented. These include all of the sessions on aeronautics and hydraulics as well as those dealing with fluid mechanics. The papers so prepared with illustrations amount approximately to a 750-page book, condensed by the off-set printing process to approximately 200 pages. The edition has been made large enough to care for those members throughout the country who may wish to obtain copies. Copies of the book may be obtained from the publisher, the George Reproduction Company, 500 Sansome St., San Francisco, Calif., at $1.50 per copy. The availability of the papers made both presentation and discussion easier and more profitable.

The success of the fluid-mechanics sessions led a number of contributors to suggest consideration, at a later time, of a joint session between some one of the engineering divisions and the section of the A.A.A.S. on physics, chemistry, or mathematics, at which session consideration of both the theoretical and applied aspects of some important phase of fundamental science might be undertaken. Not merely the subject of fluid mechanics but also those of thermodynamics, heat transmission, and applied mechanics would be benefited by such treatment.

Attendance at the several sessions was excellent. At the fluid-mechanics meetings from 125 to 150 were present; at the separate sessions from 40 to 85. A number of those attending the fluid-mechanics sessions were from the conferences on hydrology and the snow survey. The A.S.M.E. is indebted to its San Francisco Section as the sponsoring section and to the University of California and Stanford University for hospitality extended.

In the program of the meeting published in the June issue of MECHANICAL ENGINEERING the name of Edgar E. Ambrosius was omitted as one of the authors of the paper entitled "A Study of the Flow of Water Through a Glass Pipe."

Record S.P.E.E. Attendance at Cornell Meeting

THE Forty-Second Annual Meeting of the Society for the Promotion of Engineering Education was held at Cornell University, Ithaca, N. Y., June 19–23, 1934. The attendance attained the all-time record of 1109 members and guests.

This year's meeting provided two main features: The first two days were devoted to a group of conferences on numerous subjects in the curricula of engineering colleges; the general sessions followed the conferences.

For several years, as has been reported from time to time in MECHANICAL ENGINEERING, the S.P.E.E. has conducted summer schools for teachers of engineering. These have been of several weeks' duration and have been devoted to such major branches of engineering education as mechanics, engineering drawing, physics, mechanical engineering, etc. The schools have covered the list of subjects on the original program and in order to maintain the keen interest that has been aroused in better teaching as a result of them and to do so without the expense of conducting extended sessions with a repetition of the program completed last year, the conferences of this year's annual meeting were inaugurated. Some idea of the interest in the conferences can be gained from the registration of more than 900 that was recorded prior to the opening of the general sessions.

Each conference was conducted under the sponsorship of a special committee which set up the program and engaged the speakers and discussors. The conferences, many of which held several sessions, were devoted to the following topics: (1) Unit processes in chemical engineering, (2) Civil engineering, (3) Cooperative plan of education, (4) Deans and administrative officers, (5) Drawing and descriptive geometry, (6) Electrical engineering, (7) Electronics and electrical communication, (8) Engineering economy, (9) Engineering research, (10) English, (11) Fluid mechanics, (12) Heat transfer, (13) Industrial engineering, (14) Junior colleges, (15) Laboratory procedure in teaching machine production, (16) Laboratory uses of models in structures and hydraulics, (17) Machine design, (18) Mathematics, (19) Mechanical engineering, (20) Pre-college guidance and freshman orientation, and (21) Technical institutes.

In conducting the conferences papers devoted to teaching technique and problems and to subject matter were read and discussed, many of the authors having been invited from the fields of engineering practise to talk on special topics. The conferences attracted great numbers, particularly of the younger men, and served not only to stimulate better teaching methods, but also to arouse interest in the work of the S.P.E.E.

In connection with the conferences there were a number of interesting and instructive exhibits, including one of models used in teaching structures, hydraulics, and sanitary engineering, one devoted to a collection of old drawings and old drawing instruments, one which displayed a group of books on drawing and descriptive geometry, another which showed examples of student work in drawing, and one which was given over to electronics and electrical communication. These exhibits were helpful additions to the conferences.

The general sessions opened on Thursday afternoon with an address of welcome by Provost Albert Russell Mann, of Cornell. He was followed by William E. Wickenden, president, S.P.E.E., who delivered the presidential address entitled "Discipline and Discipleship." Harvey N. Davis, president, Stevens Institute, spoke on the subject "Are Engineering Schools Primarily Technical Schools?" "Readjustment of Purpose and Program in Engineering Education" was the title of a paper by R. E. Doherty, dean, Yale School of Engineering, Yale University. Gordon M. Fair, of Harvard University, spoke on "The Liberal Pursuit of Engineering Studies."

Friday morning was devoted to a symposium on the marketing of the services of the engineering-school graduate. The discussion was led by W. A. Shoudy, of Columbia University, who described the course that had been given at that institution during the past term on this general subject. He was followed by S. S. Board, employment specialist, of the

Yale Graduate's Placement Bureau, who had conducted the Columbia course.

Thursday afternoon was devoted to the presentation of numerous committee reports, including the final report of the Board of Investigation and Coordination, Charles F. Scott, chairman, which conducted the now famous study of engineering colleges and curricula that has been so frequently referred to by engineers and educators in connection with problems of engineering education.

At the annual dinner on Friday night, with President Wickenden a gracious and skilful toastmaster, the Lamme medal was presented to Prof. E. R. Maurer, and officers for the coming year were elected. A. Z. Read, of the Carnegie Foundation, and F. P. Keppel, of the Carnegie Corporation, spoke informally.

On Saturday morning the general subject was "Professional Recognition and Educational Standards." C. F. Hirshfeld spoke on the E.C.P.D. C. Frank Allen, professor emeritus, M.I.T., read a paper on the "Educational Background of Certain Distinguished Engineers," in which he listed the college training and degrees conferred on the presidents of the founder engineering societies. H. S. Rogers, president, Brooklyn Polytechnic Institute, completed the program with a paper on "Instructional Standards."

At a meeting of the S.P.E.E. Council the invitation of the Georgia School of Technology to hold the 1935 convention at Atlanta, Ga., was accepted. The Council also voted to approve the E.C.P.D. as an accrediting agency for engineering schools.

Fourth Economic Conference Meets in August

THE Fourth Annual Economic Conference for Engineers, under the sponsorship of the engineering alumni associations of several eastern colleges, The American Society of Mechanical Engineers, the American Institute of Chemical Engineers, and the American Association for Adult Education, will be held at Stevens Engineering Camp, Johnsonburg, N. J., August 11 to 19. The general theme of the conference will be "An Economic Appraisal of the New Deal."

Harvey N. Davis, president, Stevens Institute of Technology, and Prof. William D. Ennis will preside as chairmen of the sessions. Among the speakers and leaders of the conference are: Charles B. Ames, chairman of the board, The Texas Company, "Oil Production and Control Under NRA;" Chester I. Barnard, president, Bell Telephone Company of New Jersey, "Collectivism and Individualism in Industrial Management;" John D. Black, professor of economics, Harvard University, "Agricultural Planning Under the AAA;" Lyman Bryson, forum leader, Des Moines Adult Education Project, "Revolt of the Small Business Man" and "Economic Limits on Technological Advance;" William J. Cunningham, Harvard University School of Business Administration, "An Analysis of the Railroad Situation;" Carroll R. Daugherty, assistant professor of economics, University of Pittsburgh, "Labor Under the NRA Codes;" William D. Ennis, professor of economics of engineering, Stevens Institute of Technology, "Costs and Prices Under NRA;" James A. Farrell, former president, United States Steel Corporation, "Trade in a Changing World;" Louis M. Faulkner, Deputy Chamberlain of the City of New York, "Rehabilitation of City Finances;" Henry R. Hayes, former president, Investment Bankers Association of America, "Some Aspects of Utility Investments;" Kurt W. Jappe, formerly with Brookmire Economic Service, "Tariff Bargaining;" Gen. Hugh S. Johnson, administrator, National Recovery Administration, "NRA;" Benjamin S. Kirsh, counselor-at-law, "Legalities of NRA;" Leon B. Lent, executive officer, Code Authority, Scientific Instrument Industry, "Economics of Industry Planning;" James D. Mooney, president, General Motors Export Company, "Paper Money and Gold in International Trade;" Paul H. Nystrom, professor of marketing, Columbia University, "Effects of the New Deal on Selling and Advertising;" Warren M. Persons, consulting economist, "Government Experimentation in Business, 1776–1933;" Walter Rautenstrauch, professor of industrial engineering, Columbia University, "Analysis of National Income Before and During the Depression;" Col. Malcolm C. Rorty, president, American Management Association, "Democratic Premises and the New Deal;" Emanuel Stein, professor of economics, New York University, "Labor Under the New Deal;" and Q. Forrest Walker, economist, R. H. Macy & Company, "Distribution Problems Under NRA."

Members of the conference will be accommodated in the Stevens Engineering Camp buildings. A fee of $40, charged for the full session, covers all expenses. Part-time enrolments will also be accepted. For further information address The President's Office, Stevens Institute of Technology, Hoboken, N. J.

Progress in Codes and Standards

THE test code for centrifugal compressors and exhausters was approved by the A.S.M.E. Council in May, 1934. It provides standard directions for conducting and reporting tests.

The section of Instruments and Apparatus of the A.S.M.E. Power Test Codes, which covers the descriptions of various methods of smoke measurement, is now awaiting publication. The A.S.M.E. Council approved this material in October, 1933. The section on flue- and exhaust-gas analyses, which is about to be published, was approved by the Council in April, 1934.

A revision of the American national standard for screw threads, originally approved and published in 1924, is in the hands of the Sectional Committee on the Standardization and Unification of Screw Threads for approval.

The Sectional Committee on a Code for Pressure Piping is balloting on the proposed American standard code for pressure piping. Following the balloting the code will be submitted to the A.S.M.E., the sponsor organization, for approval.

A joint A.P.I.-A.S.M.E. committee has approved and released for publication the A.P.I.-A.S.M.E. Rules for the Design, Construction, Inspection, and Repair of Unfired Pressure Vessels for Petroleum Liquids and Gases. These rules have received the approval of the A.P.I. and the A.S.M.E. and it is expected that they will be available in pamphlet form in the early fall.

The proposed American standard for jig bushings has received the final approval of the Sectional Committee on the Standardization of Small Tools and Machine Tool Elements and is now before the sponsor bodies, the S.A.E., the N.M.T.B.A., and the A.S.M.E., for approval.

The proposed American standard for graphical symbols is before the Sectional Committee on Standards for Drawings and Drafting-Room Practise for approval as a preliminary step to transmission to the A.S.A. for approval and designation as an American standard.

The A.S.M.E., as sponsor organization, is now taking action on the proposed American standard for hose-coupling screw threads having nominal diameters of $^{1}/_{2}$ to 2 in., inclusive.

It is anticipated that the approval of the proposed American tentative standard for wrought-iron and wrought-steel pipe by the Sectional Committee will be completed shortly, following which it will be presented to the two sponsor organizations, the A.S.T.M. and the A.S.M.E., for action.

This Month's Authors

L. P. ALFORD, Melville medalist, A.S.M.E., draws upon a wide industrial and editorial experience in writing about standard costs. He has served as editor-in-chief of several magazines devoted to industry and management, on the editorial boards of such well-known American Engineering Council reports as "Waste in Industry," "Twelve Hour Shift in Industry," "Safety and Production," and "Recent Economic Changes," and as editor of "Management's Handbook" and the "Cost and Production Handbook." He has served actively many management and engineering societies and will be remembered in the A.S.M.E. as author of the "Laws of Management" and the ten-year progress reports on management.

Ralph S. Barnaby, on Jan. 31, 1930, made the first glider flight from a dirigible, gliding from the U.S.S. *Los Angeles* from an altitude of 3000 ft. He holds the first soaring license issued in this country and is author of a book, "Gliders and Gliding." He is a lieutenant-commander in the Construction Corps, U. S. Navy, Bureau of Aeronautics, and has been actively interested in aeronautics for many years. He is a member of several engineering societies and holds positions on many engineering and aeronautical committees and boards. He is a member of the A.S.M.E.

Peter Bier, co-author with C. M. Day, was educated as a mechanical engineer in Austria-Hungary. He has been associated with the Bureau of Reclamation since 1923, first on the design of power and pumping plants, shop inspections, and the design of the mechanical equipment and hydraulic structures for dams and power plants. Since 1927 he has been specializing on the design of large steel pipe lines, such as power penstocks and outlet pipes, siphons for canal systems, pumping lines, and pipe systems for water plants. He is a member of the A.S.M.E.

Charles M. Day has been engaged in engineering since 1900. In 1909 and 1910 he was engaged in the design of large gates and valves for the Reclamation Service under O. H. Ensign in Los Angeles and on the west coast of Mexico. Since 1912 he has been with the U. S. Bureau of Reclamation, Denver, Colo., engaged in the design of mechanical features of power plants, pumping plants, canals structures, and dams. Since 1925 he has been in charge of the mechanical department.

R. E. W. Harrison, recently appointed chief, Machinery and Agricultural Implements Division, Department of Commerce, was born and educated in England where his early designing and industrial experience was acquired. With the exception of his military service during the War, Mr. Harrison has been associated with machine-tool builders in England and in this country. In 1923 he joined the engineering staff of the Cincinnati Grinders, Inc., Cincinnati, Ohio. He has written numerous articles for the technical press and has served the A.S.M.E. as chairman of the Cincinnati Section and the Machine Shop Practice Division as chairman of its executive Committee. At present he is secretary of the Division.

E. Dillon Smith, whose article on "Dynamical Production Analysis" appeared in the June issue, completes his discussion of the general subject this month. The two articles were prepared from a paper presented at the 1933 A.S.M.E. Annual Meeting. Mr. Smith is a University Fellow at Columbia University.

A.S.M.E. Council Meets at Purdue University

MEETINGS of the Executive Committee and of the Council of The American Society of Mechanical Engineers were held at Purdue University, West Lafayette, Ind., July 1, 2, and 3, 1934. President Paul Doty presided.

At the meeting of the Executive Committee much of the time was taken up with routine matters relating to finances. It was reported that Certificates of Indebtedness to the amount of $35,350 had been subscribed by members of the Society and that $31,850 had been paid in.

A résumè was presented of the comments and suggestions received from members during the past month. Action was taken on a list of delinquent members at the recommendation of the Society's Board of Review, and numerous special cases brought to the attention of the committee by the board and the Membership Committee were given individual consideration. Upon recommendation of President Doty the Adopt-a-Member Campaign Committee was discharged with hearty thanks to its chairman, James D. Cunningham, for his faithful services.

GRAPHIC ARTS CODE COMMISSION

Harold V. Coes was appointed one of the three members on the disinterested commission to prepare the necessary regulations on the proper complement of men on relief-printing machinery. (The Graphic Arts Code of the NRA contains a provision that such a commission be named by the A.S.M.E.)

NATIONAL DEFENSE DIVISION POLICY

The National Defense Division presented a statement of policy, which the Executive Committee voted to approve, which suggested three essential elements in a program for its activities: (1) Public discussion of the basic problems of preparedness for industry; (2) Organization of advisory committees to the War and Navy Departments on such matters as the intelligent application of modern production methods to the manufacture of noncommercial munitions, and (3) Assistance in securing from the War and Navy Departments specifications for skilled professional men needed in an emergency so that the Society may develop a means of quickly determining the qualifications of its members in case of necessity.

STUDY OF COAL WITH A.I.M.E.

At the request of the American Institute of Mining and Metallurgical Engineers joint participation was authorized in a study of coals by a committee to be appointed to report not later than February 1, 1935. The study has to do with the effect of ash and moisture on the heating value of coal and on the cost of coal and ash handling, the effect of sulphur and ash-fusing temperature on the value of coal, and the effect on the value of coal of the various factors influencing combustion, such as size, presence of fines, grindability, and agglutinating and agglomerating properties.

UNITED ENGINEERING TRUSTEES, INC.

Harold V. Coes outlined some of the cooperative problems facing the United Engineering Trustees, Inc., and also pointed out the fact that the Engineering Societies Building needs refurbishing. He announced that some of the necessary repairs would be undertaken during the summer.

MISCELLANEOUS ACTIONS

The committee voted to hold the 1935 Semi-Annual Meeting at Cincinnati, Ohio.

Upon recommendation of the Power Test Codes Committee the appointment was authorized of a committee on dust-separating apparatus to formulate standard rules for testing apparatus to eliminate solid matter from flue gases. It was voted to discharge the joint A.S.M.E.-S.A.E. Diesel Fuel Oil Specifications Research Committee and the A.S.M.E. Special Research Committee on Diesel Fuel Oil Specifications.

APPOINTMENTS

The following appointments were authorized: Standing Committee on Research, Charles T. Ripley (5-year term); Standing Committee on Constitution and By-Laws, Richard Kutzleb, Jr. (unexpired term of P. R. Faymonville, 1936); Executive Committee, National Defense Division, Rear Admiral Ralph Earle (5-year term); Junior Advisors to Standing Committees, terms expiring December, 1934, (1) Publications, Oscar B. Schier, (2) Constitution and By-Laws, Gilmoure N. Cole, (3) Awards, Charles B. Arnold; Joint Research Committee on Effect of Temperature on the Properties of Metals, E. L. Robinson; Board of Review (Delinquent Dues), W. W. Macon, chairman, A. D. Blake, H. B. Oatley, and J. D. Cunningham; National Management Council, J. W. Roe, alternate for L. P. Alford, J. A. Piacitelli, alternate for J. R. Shea; American Association for Advancement of Science, Berkeley, Calif. Meeting, June 18–25, W. F. Durand, and Pittsburgh Meeting, Dec. 27, 1934–Jan. 2, 1935, S. B. Ely; Committee on Code of Practise, W. A. Shoudy, chairman, J. M. Todd, Wynne Meredith, Alfred Iddles, H. S. Philbrick, and B. F. Wood.

COUNCIL MEETING

At the meeting of the Council it was voted to approve the report of the Executive Committee covering actions taken since the previous meeting of Council.

1934–1935 BUDGET

A statement of policy prepared at the request of the Executive Committee and the Finance Committee by the Committee on Policies and Budget was approved and incorporated in the 1934–1935 budget. Numerous details of the schedule of income and expense for the budget were discussed; and with the changes suggested in the discussion, and subject to review in September, the schedule was adopted. As a result of the discussion Council expressed the view that greater publication in Transactions as soon as possible was of prime importance. It was also voted to adopt the policy that on research projects formulated from now on and submitted to outside agencies with request for financial support, provision be required that the sponsoring committee provide that a reasonable percentage of the fund collected shall be made available for a portion of the office expense necessary to administer the project. A study by the secretary of office expenses and services was requested.

MEMBERSHIP QUALIFICATIONS

The so-called minimum definition of an engineer, recommended by the E.C.P.D. (see MECHANICAL ENGINEERING, February, 1934, p. 72) was approved. It was also voted to approve in principle the recommendations of the Committee on Policies and Budget on grades of membership. (These, and other, recommendations of the Committee on Policies and Budget, discussed and approved by Council, will be presented in a later issue when it will be possible to devote more time and space to an adequate discussion of the questions involved.)

A. D. FLINN'S RESIGNATION

The Council noted with regret the resignation as secretary of the United Engineering Trustees, Inc., of Alfred D. Flinn, and adopted the following minute:

> "Upon his retirement as secretary of United Engineering Trustees, Inc., Dr. Alfred D. Flinn enters upon a period of

earned relief from his arduous duties for the engineering profession. The American Society of Mechanical Engineers regrets deeply the need for his retirement and expresses its deep appreciation of his high ideals and untiring efforts and patience in the interest of unity in the profession. Dr. Flinn left a fruitful professional career to place his abilities at the disposal of his profession which is grateful to him for his achievements. The Society hopes he will be able to continue to serve the profession as director of Engineering Foundation."

MINNESOTA SECTION

Acting upon the recommendation of the Committee on Local Sections, it was voted to authorize the consolidation of the St. Paul and Minneapolis Sections, to be designated the Minnesota Section.

VOTES OF APPRECIATION

Expressions of appreciation were voted to the loyal members and others who contributed to the success of the Denver meeting of the Society, and to the members of Purdue University for their hospitality on the occasion of the Council meeting.

New Home of Providence Engineering Society

THE Providence Engineering Society, with which the local sections of all the national engineering societies are affiliated, has purchased a building to house its activities. This new home is being renovated and will be ready for the beginning of the fall program. It is a substantial brick structure approximately 30 by 90 ft in plan view with two stories and a basement. It is located within a ten-minute walk of the down-town section of Providence and less than two blocks from Brown University campus. Approximately a third of the second floor will be used for a lounge and library and the remainder for an auditorium which will seat two hundred. For the time being the first floor will be leased for offices.

The society was able to buy the property outright and still have funds in reserve for remodeling the building. An anonymous friend has contributed money for fixing up the club rooms. As the rental of rooms will pay the operating expenses of the building it will be possible to expand activities materially with the present income from dues.

The success of the Providence Engineering Society is due to a combination of features. Since the society was organized out of the old Providence Association of Mechanical Engineers twenty years ago it has continually had conservative financial management. A budget was set at the beginning of each year and insistence was placed on operating within this budget. The policy was also adopted of putting entrance fees into a permanent fund which could not be used for operating expenses. This fund was conservatively invested. While the entrance fee is but four dollars this fund grew in twenty years to approximately $22,000. Moreover, the bonds in which it was invested were worth more than their purchase price when sold this spring.

The society has held to the policy of low dues (the members pay six dollars and juniors three dollars per year), large membership, and maximum activity. An extremely liberal policy of affiliation has always been followed, little money being contributed by the affiliated organizations and the financial returns to the Providence Engineering Society coming largely from the resulting increases in membership. As a result the society at its peak had 1200 members and still has approximately 900 on its active roll. The work of the society has been carried out by the members who have contributed their time, thought, and energy for many years. Even the detailed work of the financial secretary was volunteered until a few years ago when the practise of paying a nominal amount for such clerical service was instituted.

Another reason for the present standing of the Providence Engineering Society is that the leading engineers of the community have, without exception, taken a deep interest in the organization, given of their time, and participated in its leadership.

[We are indebted to James A. Hall, Manager, A.S.M.E., for the foregoing report.]

Five-Year Course at M.I.T.

PRESIDENT Karl T. Compton, of the Massachusetts Institute of Technology, recently announced that the Institute will offer a new five-year course which will include advanced studies in the social sciences and economics.

The new course, which in no way affects the Institute's regular four-year courses in science and engineering, will be offered next autumn in nearly all the professional fields of the Institute's curriculum.

"This new course," Dr. Compton announced, "will include essentially the same professional studies as at present in any one of the departments of engineering or science, but will also include an increasing program of more advanced studies in the fields of economics and the social sciences running through the last three years of the five-year course. In the fifth year a considerable amount of time will be devoted to a thesis on some subject which combines the professional and economic aspects of the problem which is chosen. On satisfactory completion of the fifth year there will be awarded the degree of bachelor of science in the professional field, such as civil or electrical or mechanical engineering, or chemistry or physics or biology, and also the degree of master of science in economics and engineering.

"Three considerations point to the importance and timeliness of this new development in technological education. The first of these is the certainty that applied science will play an ever-increasing role in determining our economic and social life. The second is the increasing necessity for organized cooperation, with economic and social controls, whether along the lines of the 'new deal' or on some different basis, but which, in any case, creates an urgent demand for men with an engineering training and a broad conception of relative social values and economic processes. The third of these considerations is the desirability of developing a cooperative approach to economic problems by the engineer and the economist, in somewhat the same way as has proved so fruitful in the cooperation of the engineer with the physicist, the mathematician, the chemist, and the biologist."

S.P.E.E. Elects Officers

OFFICERS of the Society for the Promotion of Engineering Education elected at the Forty-Second Annual Meeting, Ithaca, N. Y., June 19 to 23, are as follows: President, C. C. Williams, Dean, College of Engineering, The State University of Iowa, Iowa City, Iowa; vice-presidents, Prof. H. P. Hammond, Polytechnic Institute of Brooklyn, and Dean George C. Shaad, University of Kansas, Lawrence, Kans.; secretary, Prof. F. L. Bishop, University of Pittsburgh; treasurer, W. O. Wiley, John Wiley & Sons, Inc., New York, N. Y.; and members of council, Harvey N. Davis, president, Stevens Institute of Technology, Hoboken, N. J., Prof. Paul T. Norton, Virginia Polytechnic Institute, Blacksburg, Va., Prof. William T. Ryan, University of Minnesota, Minneapolis, Minn., Prof. G. P. Boomsliter, West Virginia University, Morgantown, W. Va., Dean George W. Case, University of New Hampshire, Durham, N. H., Prof. C. L. Eckel, University of Colorado, Boulder, Colo., and C. E. Davies, executive secretary, A.S.M.E., New York, N. Y.

A.I.E.E. Elects New Officers

THE following officers for 1934–1935 were elected by the American Institute of Electrical Engineers, at its meeting, Hot Springs, Va., June 25–29, 1934: President, J. Allen Johnson, chief electrical engineer, Buffalo, Niagara, and Eastern Power Corporation, Buffalo, N. Y.; vice-presidents, W. H. Timbie, professor of electrical engineering and industrial practise, Massachusetts Institute of Technology, Cambridge, Mass., G. G. Post, vice-president, Milwaukee Electric Railway and Light Company, Milwaukee, Wis., R. H. Tapscott, vice-president, New York Edison Company, New York, N. Y., F. J. Meyer, vice-president in charge of operation, Oklahoma Gas and Electric Company, Oklahoma City, Okla., and F. O. McMillan, research professor of electrical engineering, Oregon State College, Corvallis, Ore.; directors, H. B. Gear, assistant to the vice-president, Commonwealth Edison Company, Chicago, Ill., N. E. Funk, Mem. A.S.M.E., vice-president in charge of engineering, Philadelphia Electric Company, Philadelphia, Pa., and F. M. Farmer, Mem. A.S.M.E., vice-president and chief engineer, Electrical Testing Laboratories, New York, N. Y.

George W. Fuller, Chairman, Engineering Foundation, Dies

GEORGE W. FULLER, chairman of the board of The Engineering Foundation, died on June 15, 1934, at his home in New York, N. Y. Mr. Fuller, who was 65 years old, was elected to the Foundation in 1931,